USING GIS-BASED AND REMOTELY SENSED DATA FOR EARLY WINTER MOOSE (*ALCES ALCES GIGAS*) SURVEY STRATIFICATION

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A
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ABSTRACT

Stratification of moose survey areas is a key step to reduce population estimation variance. In the Yukon and Alaska, use of fixed-area grids for early winter moose counts combined with the increasing availability of GIS and remotely sensed data provide the opportunity to develop standardized and repeatable habitat-based stratifications. I used univariate comparisons, stepwise regression and AIC modeling to describe moose distribution as a function of landscape level variables for an area in west central Yukon during 1998 and 1999. Results quantified early winter habitat use of upland shrub habitats and support previous observations for early winter moose habitat use in Alaska, Minnesota and Montana. Number of patches, in association with areas of alpine and shrubs, were found to be highly influential for survey blocks where moose are expected to be present and in high numbers. Overall, model performance based on relative abundance of moose was less predictive than for blocks where moose were present or absent. Spatial resolution of GIS and remotely sensed data used in this study (25 m grid cells) provided sufficient spatial detail to generate correlations between moose presence and habitat for a first level stratification.

KEY WORDS: *Alces alces gigas*, habitat mapping, GIS, moose, remote sensing, resource selection, Yukon.

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INTRODUCTION

Accurate, unbiased and regular population estimates are necessary to manage populations of harvested moose (*Alces alces gigas*; Crichton 1987, Ver Hoef 2001). Population declines and over harvest have been attributed to a lack of adequate population data where moose are an important resource for people (Gasaway and Dubois 1987, Timmermann 1987). In North America, biologists use aerial surveys to estimate moose density, composition, trends and productivity (Coady 1982, Timmermann and Buss 1998). In the Yukon and Alaska, aerial surveys are usually carried out in early winter (Larsen 1982, Timmermann 1993; i.e. mid-October to mid-December) when moose aggregate in post-rut groups in open sub-alpine areas (LeResche *et al.* 1974, Peek *et al.* 1974, Rounds 1978, and Ballard *et al.* 1991). While aerial surveys are useful for obtaining estimates of moose abundance and population composition (Ward *et al.* 2000), costs to conduct these surveys are high and may limit their use both spatially and temporally (Courtois and Crepeau 1998, Timmermann and Buss 1998, Ward *et al.* 2000). Further, completion of early winter population surveys can be difficult due to a lack of available aircraft and poor weather conditions (e.g. incomplete snow cover to maximize moose sightability, dangerous flying conditions due to decreased visibility or high winds).

Since 1980, moose population monitoring in the Yukon has been done primarily using the stratified random block (SRB) survey technique similar to those described by Gasaway *et al.* (1986). High priority management areas were identified with the objective of monitoring moose population abundance and composition at least once every five years. While this technique was credited with providing reliable population abundance and trend data, the high-costs of conducting the surveys and gaps in timing between surveys led wildlife managers in the mid-1990's to consider more cost-effective methods to assess population trends (R. Ward, Yukon Dept. Env., *pers. comm.*). Alternative methods considered the cost-effectiveness of conducting helicopter-based surveys versus fixed-wing aircraft-based surveys (Smits *et al.* 1994), using information from stratification survey flights to estimate moose densities (R. Florkiewicz, Yukon Dept. Env., *unpubl. data*, Ward *et al.* 2000), and using composition, recruitment and harvest data to model trends in abundance. While alternative community-based moose monitoring techniques continue to be developed (M. O'Donoghue, Yukon Dept. Env., *unpubl. data*), and despite cost and field logistics during surveying, early winter aerial surveys remain the primary method for assessing moose population abundance and trends in the Yukon and other jurisdictions.

Since 1998, in response to survey method costs and concerns, a modified aerial survey method has been tested in the Yukon to estimate early winter moose densities. With this geostatistical survey method, moose are counted from the air in a sample of fixed grid-based survey blocks (about 16 km^2). Similar to the SRB technique described by Gasaway *et al.* (1986), a key component of the geostatistical survey method involves the a priori stratification of the survey area based on predicted moose abundance in sampling units. This step is essential to increase survey precision by partitioning variation in moose density among sample units (Gasaway *et al.* 1986, Lenarz 1998). In the geostatistical method, “high” strata blocks are those blocks where observers expect a high probability of seeing moose and “low” strata blocks are those blocks where observers expect a low probability of seeing moose. Typically, the decision to classify a block as a high or low is subjective and based primarily on landscape characteristics including topography, terrain, land cover type, and local knowledge of the population and area (i.e. access, harvest pressure, moose distribution in prior years etc.).

The geostatistical survey method provides the opportunity to develop habitat-based stratifications that are standardized, repeatable, and less expensive by removing the costs required to conduct aerial flights for study area stratification. Once developed, a habitat-based stratification is used from year to year for subsequent stratifications until there is a significant landscape disturbance (e.g. wildfire, logging, road developments) within a survey area. A habitat-based stratification might be applied in other areas of similar topography, vegetation and estimated moose densities to characterize highs and lows, thereby reducing potential variation in subsequent surveys and enabling comparisons between survey areas.

Habitat-based stratifications rely on the availability of land cover mapping and digital, topographic data. With the increasing ease of use and accessibility of geographic information systems (GIS) and remotely sensed spatial data, mapping of large, remote areas has become feasible (Rushton *et al.* 2004). These sources of data also permit modeling of moose-habitat relationships where on-site habitat characteristics may be costly and difficult to collect. Mapping vegetation and topography over large areas with remotely sensed data have provided a cost-effective way to analyze and stratify moose habitat in Alaska and northern Manitoba (LaPierre *et al.* 1980, Bowles 1988). Other studies have used GIS and remotely sensed data to identify important seasonal moose habitats (Allen *et al.* 1991, Erickson *et al.* 1998), address population management concerns (Suring and Sterne 1998) and to predict effects and mitigate forest management practices (Puttock *et al.* 1996). In north central Alaska, Jandt (1992) used GIS and remotely sensed data to study the role of fire in creating high quality moose habitat based on known moose densities, wildfire history and other habitat factors. Each of these studies relied on remotely sensed land cover maps, GIS, or both, to derive a suite of variables for habitat-based model development.

Moose surveys are conducted in early winter when sightability of moose is at its highest (Gasaway *et al.* 1986) and when annual post-rut, early winter moose aggregations have been found to be largest (LeResche *et al*. 1974, Peek *et al.* 1976, Rounds 1978, and Ballard *et al.* 1991). Early winter aggregations have been observed in open, upland climax shrub communities in Alaska and northeastern Minnesota (LeResche *et al.* 1974, Peek *et al.* 1976, Ballard *et al.* 1991, Gasaway *et al.* 1992). LeResche *et al.* (1974) described these timberline communities as "permanent refugia" comprised of complexes of birch (*Betula* spp.) on drier sites and dense willow (*Salix* spp.) along upland streams. These complexes are mixed with heaths, forbs, and may contain white spruce (*Picea* *glauca*) at lower elevations. Post-rut aggregations observed in Alberta also used upland sites, concentrating in aspen-dominated forests (Mytton and Keith 1981), as well as along the forest edge. In shrub communities moose were observed foraging on willow stems and fallen aspen leaves (Renecker and Hudson 1992).

Use of lowland climax shrub communities by early winter aggregations of moose has also been reported in Alaska (LeResche *et al.* 1974) and in Alberta (Hauge and Keith 1981, Mytton and Keith 1981). Late fall and early winter use of these open muskeg habitats is described by LeResche *et al.* (1974) as variable, depending primarily on seral stages of shrub growth following wildfire burns or riparian disturbance. Lowland use was reported to increase in November and December by moose in Alberta with moose congregating in open muskeg habitats dominated by mixtures of sedge (*Carex* spp.), meadows, willow flats and black spruce (*Picea mariana*; Mytton and Keith 1981, Hauge and Keith 1981).

Peek *et al.* (1976) reported similar aggregations by moose in northeastern Minnesota in open areas at upland and lowland sites in early winter and suggested use of these habitats is correlated with a requirement for growth and a recovery in fat reserves after the rut. Use of open areas and deciduous stands may provide high quality and quantity of forage sources that are needed to sustain moose through winter. Because of this reliance in early winter on these forage resources, Peek *et al.* (1976) suggested that use of these habitats could be more critical in early winter than in mid-winter and these habitats could play an important role in sustaining moose populations in northeastern Minnesota.

Finally, an investigation of early winter habitat use in southwest Yukon indicated that the majority of moose observed during early and mid-November 1982 were above treeline at elevations between 1250-1401 m, in areas dominated by shrubs, using north- and north-west facing aspects (Northern Biomes Ltd. 1983).

I investigated the feasibility of developing a habitat-based stratification model for use in conducting early winter aerial moose surveys. My specific research objectives were to:

1. Quantify and describe early winter moose habitat use in west central Yukon by comparing moose distribution to landscape-level characteristics within geostatistical survey blocks; and
2. Make recommendations based on the use and application of GIS and remotely sensed data to assist in stratification of geostatistical survey blocks.

STUDY AREA

The 5,507 km^2 study area was located in west central Yukon, Canada, next to the Yukon/Alaska border (141.00°W; Figure 1). The area is within the Klondike Plateau ecoregion, and the Boreal Northern Cordillerean Ecoclimatic Region (Ecoregions Working Group 1989). Climate is strongly continental, with warm summers and cold winters. Mean annual temperatures are near –5° C, and range from –23° to –32° C in January and 10° C to 15° C in July. Incidentally, the coldest temperature recorded in North America (-63° C) was recorded at Snag, situated at the confluence of Snag Creek and the White River in the southern half of the study area (Oswald & Senyck, 1977). Frost can occur at any time during the year, but the frost-free period typically ranges from 40-60 days (Ecoregions Working Group 1989).

Annual precipitation ranges from 300 to 500 mm, with the wettest period from June to August (Smith *et al.* 2004). Most summer precipitation originates from convective rainshowers and thunderstorms (Oswald & Senyck, 1977). Mean winter snow depth at Beaver Creek was 42 cm (1975-1999; Department of Indian Affairs and Northern Development, Water Resources, *unpubl. data*).

Smooth, rolling plateau topography with large basins are common features in the area (Ecological Stratification Working Group, 1996). The study area elevation ranges from 378 m to 1706 m and includes two mountain complexes, Felsenmeer Ridge at 1649 m, and Koidern Mountain at 1648 m. The White River flows north through the eastern portion of the study area to the Yukon River. Wetlands and associated kettle lakes cover a significant portion of the northern half of the study area, particularly within the Scottie Creek drainage. The only major lake in the study area is Fish Hole Lake located in the Wellesley Lake lowland basin in the southeast.

Treeline in the study area occurs at about 1200 m. Boreal black spruce and white spruce forests dominate below treeline although mixed stands with balsam poplar (*Populus balsamifera*), paper birch (*Betula papiferya*) and trembling aspen (*Populus tremuloides*) are also common. Open, stunted black spruce stands dominate low relief terrain and north facing slopes, with mixed forests of white spruce, aspen and balsam poplar occurring on well-drained and warmer south-facing slopes (Smith *et al.* 2004). Extensive stands of shrub birch and willow are common in alpine areas (Oswald & Senyk 1977). Permafrost is discontinuous throughout the study area.

Forest stands display the influence of wild fires in the area through the last 100 years, with seral communities of paper birch and trembling aspen, along with shrub willow and alder (*Alnus* spp.) re-growth. About 12% of the study area has been burned by wildfire since 1951.

Development in the study area is limited. The only populated community in the area is Beaver Creek (62.38°N, 140.87°W), situated on the Alaska Highway 32 km from the Yukon/Alaska border. The abandoned community of Snag, with unmaintained road access, is located at 62.40°N, 140.37°W. Land uses in the study area include hunting, trapping, limited recreation and tourism, with some placer mining claims to the north. Trails in the area are limited to the Scottie Creek valley near the Yukon/Alaska border, within a 10-15 km corridor along the Alaska Highway, and north from Snag along the White River.

Moose share this range with woodland and barren-ground caribou (*Rangifer tarandus*) and predators including wolves (*Canis lupus*), grizzly bears (*Ursus arctos*), and black bears (*Ursus americanus*). Within the study area, wolves existed at a density of about 6/1000 km^2, with pack density stable at around one pack/1000 km^2 (Yukon government, *unpubl. data*). Wolf density was considered medium to low in relation to average Yukon wolf densities and pack density was comparable to average Yukon densities (A. Baer, Yukon Dept. Env., *pers. comm.*). Grizzly bear densities in the study area were estimated at 11/1000 km^2 (Smith and Osmond-Jones 1992). Black bears existed at unknown densities.

Overall, moose harvest in the study areas is low. Annual resident hunter harvest accounted for < 1% of estimated moose in the study area (Yukon government, *unpubl. data*). First Nation harvest levels were not available, but were likely comparable to resident hunters (K. Clyde, *pers. obs.*). Localized areas of relatively high moose harvest occur along the Alaska Highway (R. Hayes, Yukon Dept. Env., *pers. comm.*), while areas to the north along the Yukon/Alaska border have minimal access with little harvest or disturbance. Local observations indicate that the moose in the study area are probably non-migratory (i.e. using the same winter and summer ranges; *sensu* Hundertmark 1998; R. Hayes, *pers. comm.*).

METHODS

Early Winter Moose Surveys

The study area was divided into 344 survey blocks, each measuring 2' latitude by 5' longitude, covering an area of about 16 km^2 each (Figure 2). In 1998, biologists (R. Hayes and L.Larocque, Yukon Dept. Env.) stratified the area into 96 blocks of "high" and 248 blocks of "low" expectation of moose presence. The stratification was based on previous knowledge of the area from two flights, flown in 1996 and 1997, and local knowledge from area residents (L. Larocque, *pers. comm.*). Based on the stratification, in 1998, 33 high blocks and 17 low blocks were selected for surveying. In 1999, the count was repeated using 38 high and 20 low blocks. In both years, about 80% of the survey blocks were selected randomly, with the remaining blocks chosen to sample areas reported to be important early winter moose habitat by area residents.

Aerial moose surveys were conducted between November 18 and 20 1998 and between October 26 and 29 1999. Survey blocks were searched intensively by experienced 2-person team (pilot and observer) in a Piper PA-18 SuperCub aircraft. Blocks were searched at a rate of ~2-3 minutes/km^2, at a height of between 150-300 m above the ground. The observers used parallel line transects within blocks of uniform topography and forest cover, ensuring complete coverage of blocks. In blocks with steep or complex terrain, observers varied their flight pattern to survey rugged terrain or to search areas of dense cover. Global Positioning System (GPS) receivers were used to identify survey block boundaries. No correction for moose missed during the survey was developed or applied to the data.

Snow in 1998 covered lower elevations but was patchy and wind blown at higher elevations. Snow in 1999 covered the entire study area at all elevations. The mean daily temperatures for survey days were -18.7°C in 1998 and -13.7°C in 1999. Relative abundance of moose in the survey blocks was assumed to not have changed significantly between 1998 and 1999. Weather conditions recorded at Beaver Creek during the 1998 and 1999 surveys are provided in Figure 3.

Land Cover Mapping

A Landsat 5 Thematic Mapper (TM) remotely sensed image for July 22 1994 (Worldwide Reference System 63/17) centered at approximately 62.85°N, 139.87°W that covered the study area was selected based the minimal cloud cover (< 1%) within the image. I used GCPWorks, a PCI 7.0 GIS module (PCI Geomatics 1999) to collect eighteen ground control points from a 1:50,000 scale digital National Topographic DataBase map and coregister the image. Ground control points were selected that were easily located on both the remotely sensed image and the vector-based topographic map (e.g. man-made features, or the edges of pothole lakes). Points were also selected from as wide an area within the image as possible to evenly rectify the image and represent topographic variation. The image was rectified using nearest neighbour resampling and using a first order polynomial transformation. Image specifications and georectification results are provided in Appendix A.

The Landsat TM image did not provide full coverage for all blocks surveyed in 1998 and 1999. As a result, a modified study area (4900 km^2) was delineated to include only those survey blocks that were fully contained within the Landsat TM image. Five blocks were excluded from 1998 survey blocks and ten were excluded from 1999 survey blocks.

Using ARC/GRID (ESRI 1999), an unsupervised multispectral classification of the Landsat TM image was conducted to develop a land cover map for the study area (i.e. Figure 4). To first differentiate between vegetated and unvegetated land cover types, I calculated a Normalized Difference Vegetation Index (NDVI) using bandwidth values recorded by the Landsat TM image, following Equation 1.

$$\mathbf{NDVI} = \frac{\textbf{Near Infrared Band - Red Band}}{\textbf{Near Infrared Band + Red Band}} \qquad \textbf{(Equation 1)}$$

The NDVI is a quantitative index that uses the characteristic reflectance properties of vegetation to establish a "greenness index" with high index values corresponding to pixels with relatively high green biomass (Campbell 1996). Conversely, low NDVI values indicate pixels of relatively low green biomass. At the time the Landsat image was recorded (mid-July), I assumed that greenness of vegetation was close to its annual seasonal peak. Using NDVI as an indicator of greenness, I conducted a cursor inquiry (Verbyla 1995) to examine the NDVI values close to areas on the image known to be "unvegetated" (e.g. lakes, rivers and roads) and vegetated areas. Further cursor inquiries of the Landsat TM image using band 6 (thermal band) enabled the separation of "cold" (e.g. clouds and snow) from "warm" (e.g. water, rock and sand) pixels. Unvegetated land cover classes were removed from subsequent analyses. With some noted exceptions, the remaining image pixels were considered vegetated.

I stratified vegetated cells using an elevation grid into three classes: nearly level (slope gradient < 5 percent), northerly facing slopes (slope gradient ≥ 5 percent and slope direction 0-89° and 271-360°) and southerly facing slopes (slope gradient ≥5 percent and slope direction 90-270°). Each stratum was separately classified into 30 spectral classes using an unsupervised classification algorithm (Ball and Hall 1965). See Table 1 for parameters used in the classifications.

To identify grouped classes, I considered comparisons with the Yukon Forest Cover digital database (DIAND 1995), spatial and topographic variability of the grouped classes, spectral responses of the grouped classes and adjacency to other grouped classes. I color-coded grouped classes to assist in visual spatial identification and cross-referenced the classes with the Yukon Forest Cover database to identify dominant forest classes (Table 2). This database covered approximately 60% of the study area. Grouped classes with similar spectral responses for level, north- and south-facing aspects were combined to represent common vegetation classes (e.g. all conifer classes were combined from level, north- and south-facing grouped classes to form "conifer forests"). Grids of final grouped classes were appended to each other to construct the final vegetated land cover map.

Habitat Variables

Using the land cover map, I derived variables for each of the vegetated cover classes. Each variable represents the percent of vegetated area in a survey block. For example, the variable "conifer" represents the percent of the survey block dominated by conifer forest.

Three other sources of data were used to derive additional habitat variables: an elevation grid, historic wildfire polygons and a first- and second-order National Topographic Database hydrology coverage. All habitat variables were derived from grids with 25-meter resolution.

Using the vegetated land cover types identified above, I analyzed the land cover map using Patch Analyst (Grid) version 2.1, an extension to the ArcView GIS system (ESRI, Redmond, CA). Patch Analyst (GRID) is an ArcView extension that interfaces with FRAGSTATS (McGarigal and Marks 1994) to generate spatial statistics that quantify landscape structure and variability. I generated a selection of landscape indices that characterize landscape pattern for each survey block based on the 25-meter resolution of the land cover map.

1. Number of different patches (NUMPATCH): the number of different landscape patches within a survey block;
2. Mean patch size (MPS);
3. Total edge or perimeter of land cover classes (TE): the total length of patch edge within the survey block;
4. Average amount of edge per patch (MPE); and,
5. Shannon's Diversity Index (SDI): a measure of patch diversity.

An elevation grid was used to estimate slope gradient, slope direction (aspect), and elevation (Figure 5). The percent of slope, aspect, and elevation classes were summarized for each survey block.

To examine moose use of wildfire burns, fire history variables for the study area were derived by converting polygons from the Yukon Fire History GIS Dataset (1946-2000) into a grid. This database maps fire perimeters for fires greater than 200 hectares. Within the survey area, fires were recorded beginning in 1951, and continued through 1999 (Table 3). No wildfires were recorded in the study area between 1967 and 1980. Less than 12% of the study area burned during 1951-1999, with few burns in blocks (*n* = 19) selected in 1998 and 1999 for the early winter moose surveys.

To examine early winter moose use of sub-alpine riparian shrub communities, buffer polygons were created from 1:50,000 first- and second-order streams. The streams were arbitrarily buffered by two distances, 15 and 50 meters, and restricted to elevations above 673 meters to create two polygon themes named BUFF15MIDHI and BUFF50MIDHI. A third buffer named BUFF 50 was created by buffering streams by 50 meters for the entire block regardless of elevation. Variables were derived based on the percent of area covered within the survey block by the buffered polygons.

Statistical Analyses

Analysis of moose distribution in relation to landscape characteristics considered differences between the presence and absence of moose in survey blocks and differences between high and low likelihood of observing moose in survey blocks. Presence and absence data provided the opportunity to consider early winter habitat use and availability differences. To further consider differences between survey blocks, I investigated differences between high or low numbers of observed moose in survey blocks. "High" spatial survey blocks were defined as blocks with ≥ 2 adult moose observed. Survey blocks with < 2 adult moose were defined as "low". Thus, the range of observed moose in blocks is greater in the "high" strata, so that lows will consistently be areas where moose are unlikely to be counted, and is consistent with the geostatistical survey method (R. Hayes, *pers. comm.*). Survey blocks in 1998 and 1999 with zero counts were included and stratified as lows to examine landscape characteristics where moose were absent, similar to those blocks with low (< 2 adult moose) moose counts.

For survey blocks sampled both in 1998 and 1999, moose were considered present if they were observed in either year. If moose were counted in a block during both years, the moose count for 1999 were used to classify blocks as high or low, as snowfall conditions in 1999 best represented the area (L. Larocque, *pers. comm.*). A two-way ANOVA was used to test for differences between the number of moose counted in survey blocks between the two years.

Data for the surveyed blocks were standardized against all blocks that comprised the study area. For the variables that represented proportional (or percent) data, an arcsine transformation was conducted to transform these data from binomial to normal distributions (Zar, 1984). Mean study area variable values were then subtracted from surveyed block variable values and divided by mean study area standard deviation variable values.

Univariate differences between presence and absence and high/low numbers of observed moose in survey blocks by explanatory variable were assessed using pairwise comparisons using *t*-tests. Due to non-normalcy, univariate comparisons for the three wildfire burn variables used non-parametric Mann-Whitney *U*-tests. I used Bonferroni adjusted probability values to assess the experiment-wise error rate. Probability values from the pairwise tests were multiplied by the number of variables originating from a source of data (i.e. each probability value of the 10 variables derived from the elevation grid were multiplied by 10) to provide experiment-wise error protection. All statistical analyses were performed using SYSTAT version 10.0 (SPSS Inc. 2000).

Model Development and Assessment

Stepwise Regression

Stepwise regression (LOGIT) models were developed for survey blocks with or without moose and for blocks with expected high or low numbers of moose as a function of vegetation and topographic predictor variables. This step provided a preliminary opportunity to identify combinations of variables for model development. The goal of model development was to find the best fitting, yet biologically reasonable model to describe the relationship between moose distribution and the vegetation and topographic predictor variables (Hosmer and Lemeshow 2000). An example of a logistic regression equation with multiple explanatory variables is represented below (Neter *et al.* 1996).

$$\mathbf{Y} = \frac{\exp^{(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p)}}{1 + \exp^{(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p)}} \qquad \textbf{(Equation 2)}$$

For the equation, Y is the probability that moose will be present or absent in a survey block, where β_0 is a constant, X_1 to X_p are predictor variables, and β_1 to β_p are the variable coefficients. Thus, the model would estimate the probability that a survey block would have moose present or absent, or high or low numbers of moose based on the variables measured.

I assessed multicollinearity of all variables in a global logistic model, identifying those variables with a variance inflation factor (VIF) greater than 10 (Table 4). Variables with a

VIF >10 were considered highly correlated. Selection of which correlated variables to remove considered whether the variable could otherwise be represented by a surrogate variable (e.g. removal of HIELEV could otherwise be represented by ALPINE).

I developed separate LOGIT models for topographic variables (slope, aspect, elevation), for vegetated variables, and for the remaining habitat variables (buffered drainages, burned areas and patch statistics) to consider potential predictors based on their data source. I used backward stepwise modeling and variables with p-values greater than 0.15 were removed from the model. Fit of the LOGIT models was assessed using the log-likelihood statistic, model prediction success tables (i.e. classification error rate), and the Hosmer-Lemeshow lack-of-fit test (Hosmer and Lemeshow 2000).

AIC Modeling

The importance of landscape and vegetation in early winter for moose foraging has indicated the importance of open, upland climax shrub communities (LeResche *et al.* 1974, Peek *et al.* 1976, Ballard et al. 1991, Gasaway *et al.* 1992), lowland climax shrub communities (LeResche *et al.* 1974) and open muskeg habitats (Hauge and Keith 1981, Mytton and Keith 1981). To examine moose use of these habitats, and considering the results of the LOGIT models, I selected a set of *a priori* variables to further examine model inferences and identify a parsimonious model supported by the data (Tables 5 and 6). I used the sample-size corrected equation of Akaike's Information Criteria (AIC_c;

Burnham and Anderson 2002) to conduct this investigation. This method identifies the best-fitting model relative to the set of candidate models considered (Burnham and Anderson 2002).

$$\mathbf{AIC_c = -2LL + 2K + \frac{2K\,(K+1)}{(n\text{-}K\text{-}1)}} \qquad \textbf{(Equation 3)}$$

For AIC_c, the –2LL is the calculated log likelihood from the regression equation, n is the sample size, and K is the number of estimable parameters in the regression equation. The second and third terms of Equation 3 will increase the AIC_c value as the number of predictor variables in the model increase. As a result, the AIC_c value helps to identify the most parsimonious model given the set of models considered. This approach has been advocated to address potential overfitting of models to data, particularly when a large number of predictor variables are considered (Anderson *et al*. 2000).

Differences between the AIC_c values for models were calculated and used to rank models within the set and to address uncertainty in model selection. Models with differences in the relative rankings less than or equal to 2 were considered to be the best approximating models for the data set (Burnham and Anderson 2002). Akaike weights (w_I) were calculated and used as a comparative measure of evidence that model $_i$ is the model that best minimizes information loss given the full set of *R* models (equation 4; Burnham and Anderson 2002). Evidence ratios were used to compare Akaike weights w_i/w_j between models.

$$w_I = \frac{\exp(-1/2\Delta_i)}{\sum_{r=1}^{R} \exp(1/2\Delta_r)} \qquad \textbf{(Equation 4)}$$

The relative importance of each predictor variable in the models was assessed by summing Akaike weights for all models that included that predictor variable. This provides an indication of influential variables in the ranked models.

RESULTS

Early Winter Moose Surveys

Early winter moose surveys completed in 1998 and 1999 covered a slightly larger area (5507 km^2) than the study area (4900 km^2). The moose count and density estimate tended to be higher in 1999 compared to 1998 (Table 7), probably because counts were completed earlier in 1999 when post-rut groups were more cohesive. However, in blocks that were sampled in both years ($n = 22$), moose counts did not vary between years ($F_1 = 0.035$, $P = 0.853$), therefore data were pooled for both years to increase the sample size. The moose density in the area is higher than the average Yukon density estimate (150 moose/1000 km^2), but is comparable to other naturally occurring low-density populations in the southwest Yukon (Yukon Territorial Government 1996). Survey costs were approximated at \$7.60/km^2 of surveyed area per year (L. Larocque, *pers. comm.*). Moose counts by survey block are shown in Figure 6.

Land Cover Mapping

Nine land cover classes were generated for the study area; six vegetated and three unvegetated (Figure 7). The vegetated classes used for subsequent analyses were shrub, conifer forest, muskeg/bog, mixed forest (broadleaf/conifer), broadleaf forest and alpine. These six vegetated classes comprised 95.6% of the study area (Table 8).

Moose Presence and Absence

Univariate Analyses

Moose were more likely to be present in survey blocks:

- at high elevations (i.e. ≥1000 m);
- with high slopes;
- with large areas of alpine; and
- with large patches of vegetation with little edge ($P < 0.05$; Table 5).

Moose were less likely to be present in survey blocks:

- with low slopes;
- dominated by mixed forests;
- with higher relative numbers of vegetation patches;
- with large amounts of patch edge; and
- with a high diversity of patch types ($P < 0.05$; Table 5).

Stepwise Regression

For topographic variables, the simplest multivariable model that predicted the probability that survey blocks had moose present or absent used percent of survey block at high elevation (Table 9). For vegetated variables, the simplest multivariable model included three predictors percent of survey block dominated by mixed forest, broadleaf forest and low-lying muskeg (Table 10). Finally, for the remaining habitat variables, the simplest model to predict the probability of blocks having moose present or absent had one predictor variable, number of patches in a survey block (Table 11).

Model Assessment

Following information theory (Burnham and Anderson 2002), models with the lowest AIC_c values are considered the most supported by the data. The model that best discriminated between survey blocks where moose were present and blocks where moose were absent used one predictor, the number of patches per survey block. The model had a low Akaike weight of 0.245 (Table 12), indicating weak support of this model as the "best" model among the set of models considered (Burnham and Anderson 2002). Models that included number of patches per survey block in combination with areas of shrub, mixed forest and alpine, as well as areas burned between 1974 and 1999 had comparable evidence ratios not exceeding 2.722 (Table 12). For the top two models, number of patches and number of patches in combination with areas of shrub, the parameter estimate for the number of patches per survey block remained stable regardless of which additional parameter was added to the model (Tables 13 and 14), indicating the relative importance of the variable number of patches within this set. This model correctly classified survey blocks where moose were present 81.9% of the time. Classification success for blocks where moose were absent was comparatively less however, only classifying blocks correctly 42.4% of the time.

The second best and competing model included number of patches and percent of survey block area with shrubs (Table 14). While the area of shrubs was included in the second best model, the variable could not be considered a useful predictor since its 95% confidence interval contained the value of 1, and the direction of selection could not be determined. Using this model, classification accuracy increased only slightly for blocks were moose were present to 82.2% of the time, and to 43.5% of the time for blocks where moose were absent.

High/Low Numbers of Observed Adult Moose

Univariate Analyses

High numbers (≥ 2) of adult moose were observed in survey blocks:

- at high elevations (i.e. ≥1000 m);
- with moderate and high slopes;
- with large areas of alpine; and
- with large patches of vegetation with higher relative patch/edge ratios ($P < 0.05$; Table 6).

Survey blocks with low numbers of moose were characterized by areas:

- at low elevations;
- with slight slopes;
- dominated by areas of mixed forests;
- with higher relative numbers of vegetation patches;
- with large amounts of patch edge; and
- with a high diversity of patch types ($P < 0.05$; Tables 6).

Stepwise Regression

Backward stepwise methods resulted in a model for topographic variables that included percent of survey block with southeast aspect, and with high elevations (Table 15). The model that considered vegetated variables identified one predictor variable, percent of block dominated by alpine (Table 16). For the remaining habitat variables, the simplest model included number of patches in a survey block and the total area burned by wildfire (Table 17).

Model Assessment

Using AIC modeling, the model that included number of patches per survey block, and percent of survey block area alpine best discriminated between survey blocks with high and low numbers of adult moose (Table 18). This model correctly classified 71.9% of survey blocks with high numbers of adult moose, and 59.3% of low numbers of adult moose.

The second best model contained one variable, the number of patches per survey block. Based on the ratio of Akaike weights between this model and the first model (evidence ratio = 2.082), there was relative support for competition between these two models. However, the classification accuracy for the model containing only number of patches decreased to 70.6% for blocks where moose were present, and to 57.4% for blocks where moose were absent when the variable area of alpine was not included in the model.

The third best model included number of patches per survey block, area of alpine, and area burned between 1974 and 1999. This model improved classification accuracy slightly to 72.2% for blocks where moose were present, and to 59.7% for blocks where moose were absent. The addition of the variable area burned between 1974 and 1999 could not be considered useful however, since the 95% confidence intervals for the odds ratio included the value of 1 and the direction of selection could not be determined (Table 21). The remainder of the models considered in the set had $AIC_c \geq 2$, and were not likely the best models, given the data (Burnham and Anderson 2002).

DISCUSSION

I developed models that described moose distribution as a function of landscape level variables to aid in developing a spatially explicit stratification for use in early winter moose surveys. Within this region, early winter habitat use by moose was consistent with characteristics documented for other seasonal aggregations of moose in mountainous terrain (LeResche *et al.* 1974, Peek *et al.* 1974, Coady 1982, Doerr 1983, Northern Biomes Ltd. 1983, Ballard *et al.* 1991). Adult moose were present and in high numbers in high elevation areas dominated by large areas of alpine and shrubs. These areas had large, homogenous patches of vegetation with higher relative patch/edge ratios, and were in areas with moderate and high slopes. These habitat characteristics describe the climax upland habitats that LeResche *et al.* (1974) identified as permanent forage-based refugia for low-density moose populations. These refugia in climax shrub communities constitute a relatively stable source of forage and likely support a nucleus population of moose from which individuals may rapidly colonize seral habitats caused by burns or other disturbances (Geist 1971). In areas of low density populations and in the absence of burned habitat, these stable, climax habitats provide important browse particularly in late fall and early winter when forage quality declines (Peek *et al.* 1974). At those critical times, moose selectively forage and use areas that are most capable of satisfying their nutritional needs (Geist 1974, Renecker and Hudson 1992). It follows that greater seasonal use and aggregation of moose will occur in these upland climax shrub communities (Schamberger and O'Neil 1986), when considered independently from other factors such as intra- and inter-specific competition, and population density.

The role of these upland climax habitats has been further characterized as critical for moose in early winter. Peek (1998: 375) notes “the nature of late autumn and early winter habitats influence the condition of moose entering severe times of winter”. Following the rut, foraging is the predominant activity of bulls when they need high quality and quantity forage to replenish fat reserves (Peek *et al.* 1976) needed for successful over wintering (Miquelle 1990).

Generally, these alpine shrub habitats remain relatively uninfluenced by fire (Van Ballenberge 1992, Peek 1998), are extensive throughout interior areas of Yukon/Alaska below elevations of about 1250m (Viereck 1979), and are consistently productive retaining high biomass annually (LeReseche *et al.* 1974, Van Ballenberghe 1992, Peek 1998). Also, in high-elevation riparian areas, the density of willow stems may be very high (LeResche *et al.* 1974). In early winter, shrubs in these habitats are likely preferred by moose due to their accessibility. In other parts of the study area, and in particular along riparian areas bordering the White River, several species of willows exist most likely as a result of erosion and flooding processes. These shrub communities are not, however, heavily used by moose possibly because they have outgrown the reach of moose (R.Hayes, *pers. comm.*). LeResche *et al.* (1974) similarly noted that early winter moose use of riparian communities in the Tanana Flats area of Alaska was low where willows are old and extremely decadent.

Characteristics of survey blocks used by moose in the study area indicated a preference for areas with larger patches with higher relative amounts of patch edge. This result is consistent again, with the characteristics of upland, open treeline shrub habitats that often form a discontinuous, patchy mosaic that may be limited in size and distribution. Patches of favourable habitat may be contained within larger areas of either unsuitable or low quality habitat. In early winter moose aggregate in these habitats before snowfall accumulation may trigger migration (e.g. >40-60 cm; Coady 1974, Van Ballenberghe 1992) into forested habitat types (LeResche *et al.* 1974, Ballard *et al.*1991, Puttock *et al.*1996).

Moose also were reported to use open habitats (i.e. large patches) in early winter in northeastern Minnesota (Peek *et al.* 1976) and in northern British Columbia (Schwab and Pitt 1991). In Minnesota, Peek *et al.* (1976) reported that open areas with the highest forage biomass were used in late fall and early winter, and were the major habitats supporting the density, production and survival of the population. Large aggregations of moose were also reported in the Kenai Peninsula, Alaska, where moose used open alpine tundra or open shrub communities during the post-rut period (Peek *et al.* 1974). In northern British Columbia, moose used more open canopy cover types, where clear-cuts had occurred < 20 years prior, and where some patch retention remained (Schwab and Pitt 1991). In that case, forage was found to explain canopy cover selection in early winter. Peak daily movements for moose in Denali National Park, Alaska have been observed in November as moose use forage supplies at high elevations during the post-rut (Van Ballenberghe 1992). Thus, early winter habitat preferences may be primarily driven by forage selection in high elevation, patchy habitats and secondarily by cover requirements.

Moose presence in survey blocks indicated a preference for areas with moderate and high slopes (>4°). Ballard *et al.* (1991) reported similar results during autumn (Sept.-Dec.) with moose selecting gentle (11°-30°) and moderate (≥ 30°) slopes and avoiding flat (≤ 10°) areas. Within the study area, slope generally increased with elevation. Use of moderate and high slope terrain by moose was correlated with high elevations, and again, relates to moose use of open, alpine and shrub areas near treeline.

The resource selection models generally supported the univariate results. Moose use (presence/absence) was positively correlated with the amount of area with shrubs and alpine (Table 10) and negatively correlated with block patchiness (Table 11). For high and low numbers of moose, a negative relationship with the area of survey block burned in the past 25 years was also identified. Wildfire burns play an important role in creating successional browse for moose (LeResche *et al.* 1974) and significant early winter use of these areas has been documented elsewhere (Jandt 1992). However, within this study area less than 6% of the entire study area has burned in the last 25 years (Table 3), and within the blocks surveyed blocks, only 4.4% of the area burned. Given the high counts of moose in some survey blocks, the variable representing survey block area burned in the past 25 years may be influential where surveyed blocks overlap with areas burned. Therefore, the influence of habitats burned in the past 25 years for this study should be considered with caution. This variable representing area burned in blocks in the past 25 years, was also problematic when considered in the model with number of patches and area of alpine as a predictor for high and low numbers of moose, since its direction of selection (i.e. high or low) could not be determined in the model.

The model containing only the number of patches within a survey block correctly classified 81.9% of blocks where moose were present. The model was comparatively poorer when used to predict blocks where moose were absent; predicting absence correctly only 42.4% of the time. Thus, while the number of patches is a highly influential variable accounting for model variance where moose are present, it is less influential accounting for areas where moose are absent.

The model's strength in predicting moose presence in survey blocks is more important than its failure to predict their absence. Because moose are grouped in these habitats in early winter, accurate prediction of survey blocks with moose present will likely identify where these aggregations will be. False predictions of moose absence in blocks where moose were present may represent cases where moose were traveling in poor quality habitat blocks to get to a nearby block of better habitat. This is a noted limitation of the model as it may incorrectly identify unused habitat (Boyce and McDonald 1999). It is not however one that should limit application of it for stratification purposes since it is assumed that due to seasonal aggregations, surveying present blocks will capture a representative population sample. By placing this potential variance in the "present" or "high" counts, this limitation of mispredicting used habitat should be minimized.

Overall, model performance based on high and low numbers of moose, was less predictive than for the model based on presence or absence. When the blocks were considered based on high (≥ 2) and low (< 2) moose numbers, the model containing number of patches within a survey block and the percentage of survey block area dominated by alpine explained a higher amount of model variance for survey blocks with high numbers of moose. This model accounted 71.9% of model variance for blocks with high numbers of moose, compared to 59.3% of model variance accounted for blocks with low numbers of moose (Table 18). When compared to the classification accuracy for blocks stratified based on the presence or absence of moose, for purposes of survey area stratification, identifying simply where moose are present or absent produces a better overall stratification than based on where there are more or fewer numbers of moose. This supports the study design for the geostatistical survey method where expected variation in moose numbers within survey blocks should be stratified as "high" probability of seeing moose, leaving blocks stratified as "low" having little probability of seeing moose.

These results are based on a moose population that existed at low densities comparable to other northern moose populations found in similar habitats (Table 28-1; Franzmann 2000) in interior Alaska (Bertram and Vivion 2002) and in the Mackenzie Valley, Northwest Territories (Stenhouse *et al.* 1995). Van Horne (1983), Hobbs and Hanley (1990), and Schamberger and O'Neil (1986) recommend caution when developing inferences about habitats used by low-density populations, since these habitat associations may be misleading. However, Peek (1998; supported by Van Horne 1983) argues that since some habitats provide important forage at a critical time, regardless of densities, moose will seasonally select the same habitat type. Because this study focuses specifically on early winter moose habitat associations, the relationship between moose distribution and habitat associations is not likely confounded by within-year seasonal variation of habitat use (Schooley 1994, Boyce and McDonald 1999). When forage is limited in early winter (in part due to freezing of aquatic communities at lower elevations), aggregations of moose where forage is accessible (e.g. upland climax shrub communities) results in seasonal use of habitats where forage biomass can be reliably obtained. Thus, I argue that early winter aggregations of moose using areas with the habitat characteristics identified in this study will likely occur regardless of changes in population densities.

Limitations of this study

Habitat association studies have been criticized primarily for incorrectly interpreting study correlations as cause and effect (Wolff 1995). Typically these studies consider only proximate factors (e.g. landscape level habitat variables) and describe patterns of use by wildlife and not the underlying selection processes or ultimate factors (i.e. a food source; Wolff 2000). Although satellite-derived data provides an opportunity to examine habitat over large and remote areas, I recognize that these data are only surrogates for habitat predictors (Rushton *et al.* 2004). Results from this study provide a general indication of habitat relationships, but at a finer scale other variables may be influential in habitat selection and preference. With this in mind, inferences beyond the landscape level of habitat associations addressed in this study are limited.

Both the boundaries for the study area and the grid-based survey blocks were delineated based on the requirements of the geostatistical survey method. The boundaries for the study area and survey blocks did not conform to terrain classes, or hold ecological meaning in relation to moose habitat use. Rather, the size of the study area was designed to cover the area of interest, while providing an adequate sample of uniform-area survey blocks to estimate population size in the area. Delineation of the area in the manner requires consideration of an underlying spatial analysis principle – the sensitivity of the statistical results to the definition of the areal units, also known as the modifiable areal unit problem (MAUP; Fotheringham and Wong 1991, Svancara *et al.* 2002). Grid-delineated boundaries have been described as “arbitrary” and lacking “biological meaning” (Dudley 1991, Svancara *et al.* 2002). While the study area boundary used in this study was subjectively delineated within the area of interest, the 4900 km^2 area certainly supports a substantial number of moose home ranges. Moose home ranges vary from 111 km^2 and 274 km^2 (R. Ward, *unpubl. data*, Ballard *et al.* 1991) in the Yukon and south central Alaska range. Local observations further note that moose in this area are considered non-migratory, with seasonal movements that primarily vary over elevation, rather than covering long-distance migrations (R. Hayes, *pers. comm.*). Further, the implementation of the geostatistical survey method followed the use of habitat-based survey blocks designed to capture areas with uniform moose densities defined by Gasaway *et al.* (1986). The latter arguably represented more "biologically meaningful" boundaries, but difficulties identifying survey block boundaries on the land often made surveying problematic when determining if observed moose were in or out of survey block boundaries. Fixed area survey blocks designed using the geostatistical method likely improve survey precision by enabling both a pilot and observer to look for moose (because the boundaries of the unit are easily linked to GPS in aircraft), and efficiently sample blocks that are easily visible. This translates into reduced flight times, hence enabling surveys of more sample units. The uniform size of the survey blocks further improve the precision of population estimation by decreasing variance between blocks based on sample size (Gasaway *et al.* 1986). Considering the reasonable precision of population estimates that use of a grid-based delineated survey area and sample units, and given this study identified landscape level habitat associations, the need for biologically meaningful boundaries is not a key requirement in developing a habitat-based stratification. At the time of this study, the geostatistical method was in wide use throughout the Yukon and Alaska. Fixed area blocks allow for the combination of adjacent study areas and comparisons of data, thereby providing an important practical incentive in support of using these units over non-fixed area blocks. However, any changes to the size of sample units or even to the resampled pixel size of the satellite image would result in changes to the model fit, regression parameters, or correlation coefficients (Svancara *et al.* 2002).

Early winter surveys are designed and timed to coincide with known moose use of open habitats, when moose aggregate and are visible in shrub and alpine habitats (Larsen 1982, Peek *et al.* 1974, Lynch 1975, Gasaway *et al.* 1987). Novak (1980) recommends that these surveys be conducted as early after snowfall and foliage drop as possible to facilitate easier sightings, before bulls drop antlers, and before snow accumulates to levels that inhibit movement of moose resulting in movements to areas with increased forest cover. Generally, assumptions about habitat use at this time should reflect equal availability of habitats across the study area, and that moose will independently select habitats based on a pool of available habitats (Arthur *et al.* 1996). Study design in early winter however, necessitates sampling patterns that are generally non-random for a portion of the blocks sampled, and reflect the spatial pattern of preferred early winter habitats. As a result, the effect of spatial autocorrelation, the tendency of measurements at nearby locations to resemble on another (Campbell 1996), may be present and may overestimate habitat associations described in this study. This bias however, is somewhat offset by also surveying blocks with expected low probabilities of seeing moose and by the largely random selection of about 80% of survey blocks.

There are important qualifications underscoring the results of my study. The relationships between moose distribution and landscape characteristic use that were investigated focused on habitats derived from available spatial, digital data. Other factors may influence annual early winter moose distribution including predation, harvest pressure, weather conditions, and patterns of population aggregations due to social and behavioral interactions (O'Neil and Carey 1986, Wolff 1995, Peek 1998). Although the intent of this study was to quantify habitat associations based primarily on available habitat data, more detail about these factors should improve the stratification, where information is available. Regional biologists often best understand the influence of these factors either from regional investigations or through local observation. When this information is available, it should be applied for a second-level stratification.

CONCLUSIONS AND RECOMMENDATIONS

The habitat association models examined in this study considered where moose are in early winter for a low-density population, in a northern region. This work provides a landscape-level description of these habitat associations, useful for stratifying survey areas into areas of expected presence and absence of moose. At a second level, detail about harvest and predation pressures, effects of access, and local understanding of moose movements and habitat use in early winter should contribute to a finer understanding of habitat associations. Active "adaptive management" to refine this work through mensurative studies would further help to determine what drives these habitat association relationships (Wolff 2000, Osko *et al.* 2004). With added replications (additional survey blocks, years, and areas), investigation of underlying relationships, criticisms about the transferability and application of this study's findings may be addressed. The main value of this study is that it indicates a quantifiable pattern and relationship in early winter between moose distribution on the landscape and patchy, upland shrub communities. Further, this study demonstrates a practical method to assess early winter habitat associations using GIS-based and remotely sensed data.

Recommendations for conducting habitat-based stratifications

Continue to improve the quality and availability of vegetation classification and spatial data to support habitat-based stratifications.

At the time of this study in the Yukon, about 80% of the territory was classified based on land cover at a 30m grid scale. Much of this work is tied to other resource-based planning initiatives based on territory-wide land-based development priorities. As this research proceeds, more complete, ground-truthed classifications will further improve data availability for wildlife managers. Availability and consistent formatting of data are key factors for improving habitat-based stratifications. Completed land cover classifications can then support the development of habitat structure, pattern and complexity variables using patch statistics and the FRAGSTATS ArcView extension used in this study.

Further investigate the usefulness of local knowledge about predation, harvest pressure, etc. to "fine-tune" the classification.

The habitat-based stratification proposed through this study offers a broad classification over large, remote areas for low-density moose populations where stratification flights may be costly. Additional local knowledge (e.g. from area residents or an area biologist) may provide further insight into populations, particularly for low-density populations, as more information about the survey area becomes available over time.

Broadening the knowledge base will help to identify survey blocks that when considered based solely on habitat appear to be a "high" (i.e. exhibit habitat potential to contain moose), but may not be because of other influences. In turn, the improved stratification will enable a reduction in survey flight times, and enable surveys of more blocks. The result overall is an increase in survey precision by reducing variance.

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TABLES

Table 1. Clustering criteria used in ISOCLUSTER of Landsat TM Image stack of Bands 3, 4 and 5 for the study area in west central Yukon.

ISOCLUSTER Criteria	User-defined settings
Number of classes to group cells	30
Number of iterations of the clustering process.	20
Minimum number of cells in a valid class	20
Interval of sampling	10

Table 2. Example of reference data used to classify north facing vegetation classes from the Yukon Forest Cover Database. W = white birch (*Betula papyrifera*); Sw = white spruce (*Picea glauca*); Sb = black spruce (*Picea mariana*); A= trembling aspen (*Populus tremuloides*); Alpine = vegetated land above timberline.

Forest Cover Polygon No.	Hierarchical Class Group Number	Species	Percent Polygon Coverage of Classes	Age (yrs)	Ave. Height (m)	Polygon Coverage of Classes
462	3, 2, 4	W, Sw, Sb, A	60, 20, 10, 10	80	18	90
498	2, 3, 4, 6	W, Sb	60, 40	80	14	90
482	5	Alpine	100	-	-	50
822	2,4	Sw, W	60, 40	150	12	90
317	3, 6	A, Sw	70, 30	80	9	90

Table 3. Area burned by wildfires within the study area in west central Yukon, 1951-1999. Years not listed were not burned by wildfire.

Year	Area (km^2)	Percent of Study Area Burned
1951	231.25	5.03
1953	12.55	
1954	2.84	
1966	9.17	< 1.00
1967	0.46	
1980	3.66	< 1.00
1982	41.95	
1990	27.98	5.39
1991	40.40	
1992	61.20	
1994	5.77	
1997	34.81	
1998	93.90	
1999	0.00	

Table 4. Model variance inflation factor (VIF) results for variables used in this study. Global model VIF results are shown in column VIF^1; VIF results for the subset of variables used in AIC modeling are shown in column VIF^2.

Variable	**VIF^1**	**VIF^2**
NE	7.96	-
SE	7.56	-
SW	9.06	-
NW	6.57	-
LOELEV	114.01	-
MIDELEV	61.08	-
HIELEV	83.48	-
SLSL	103.18	-
MSLOPE	54.20	-
HSLOPE	19.40	-
ALPINE	30.00	2.45
BROADLEAF	6.75	-
SHRUB	7.70	1.69
CONIFER	10.09	-
MIXED	14.29	3.34
WET	17.97	-
BUFF50	9.26	-
BUFF15	7.63	-
BUFF15MIDHI	21.16	-
BURN LT 1974	417.64	-
BURN 74-99	190.72	1.02
TTLBURN	543.58	-
NUMPATCH	171.73	2.56
MPS	63.05	-
TE	181.47	-
MPE	60.38	-
SDI	4.21	-

Table 5. Pairwise comparisons of topographical values (%), vegetative cover (%), buffered drainage features (%), burned areas (%) and patch characteristics for survey blocks (16 km^2) with grid cell resolution of 25 m^2, where adult moose were present (n = 54) and absent (n = 17) in west central Yukon, early winter 1998 and 1999. Bolded text identifies significant results. Mnemonic codes are in Appendix B.

Variable	**Present**		**Absent**		**Test Statistic** [A]	
	Mean	**SE**	**Mean**	**SE**	t	P [B]
Topographical Data						
NE [D]	-0.17	0.07	- 0.23	0.12	-0.422	1.000
SE [D]	0.12	0.07	0.18	0.13	0.447	1.000
SW [D]	0.28	0.08	- 0.01	0.16	-1.819	0.732
NW [D]	0.07	0.06	0.12	0.12	0.369	1.000
LOELEV [D]	-0.99	0.19	0.06	0.36	2.619	0.108
MIDELEV [D]	0.02	0.14	0.10	0.28	0.270	1.000
HIELEV [D]	1.26	0.21	- 0.16	0.19	-3.691	**0.004**
SLSL [D]	-0.34	0.15	0.53	0.26	2.928	**0.046**
MSLOPE [D]	0.51	0.10	0.05	0.20	-2.153	0.348
HSLOPE [D]	1.15	0.19	- 0.09	0.32	-3.196	**0.021**
Vegetative Cover						
ALPINE [D, E]	0.87	0.18	-0.12	0.15	-3.008	**0.040**
BROADLEAF [D]	0.18	0.12	0.48	0.25	1.194	1.000
SHRUB [D, E]	0.55	0.15	0.19	0.23	-2.502	0.162
CONIFER [D]	-0.14	0.11	-0.17	0.20	0.512	1.000
MIXED [D, E]	-0.80	0.14	-0.02	0.23	3.415	**0.012**
WET [D]	-0.49	0.14	0.00	0.24	1.778	0.878
Drainage Feature Codes						
BUFF50 [D]	-0.08	0.12	-0.30	0.28	-0.833	1.000
BUFF15	-0.06	0.12	-0.16	0.17	-0.382	1.000
BUFF15MIDHI	0.68	0.15	0.18	0.34	-1.537	0.386

Table 5. (Continued)

Variable	**Present**		**Absent**		**Test Statistic** [A]	
	Mean	**SE**	**Mean**	**SE**	***t***	***P*** [B]
Burned Area Codes						
BURN LT 1974 [C]	0.18	0.17	0.36	0.40	474.500	1.000
BURN 74_99 [C, D, E]	-0.20	0.11	0.02	0.26	514.000	0.660
TTL BURN [C, D]	-0.02	0.14	0.31	0.33	534.000	0.230
Patch Characteristics						
NUMPATCH [D, E]	-0.71	0.14	0.61	0.24	4.788	**<0.001**
MPS	0.03	0.01	-0.02	0.01	-4.483	**<0.001**
TE	-0.75	0.14	0.63	0.24	4.984	**<0.001**
MPE	0.68	0.15	-0.42	0.16	-3.939	**0.002**
SDI [D]	-0.51	0.13	0.30	0.14	3.366	**0.014**

[A] Two-sample *t*-test; d.f. = 69

[B] Bonferroni adjusted probabilities.

[C] Mann-Whitney *U*-test, d.f. = 1

[D] Variables used in multivariate analysis, after testing for multicollinearity.

[E] Variables used in AIC modeling.

Table 6. Pairwise comparisons of topographical values (%) vegetative cover (%), buffered drainage features (%), burned areas (%) and patch characteristics for moose survey blocks (16 km^2) with grid cell resolution of 25 m^2, with high (≥2 moose, $n = 42$) and low (< 2 moose, $n = 29$) numbers of adult moose in west central Yukon, early winter 1998 and 1999. Bolded text identifies significant results. Mnemonic codes are in Appendix B.

Variable	**High**		**Low**		**Test Statistic** ^{A}	
	Mean	**SE**	**Mean**	**SE**	t	P^B
Topographical Data						
NE ^{D}	-0.17	0.07	-0.21	0.09	0.298	1.000
SE ^{D}	0.09	0.08	0.20	0.09	-0.869	1.000
SW ^{D}	0.30	0.08	0.09	0.13	1.446	1.000
NW ^{D}	0.13	0.06	0.01	0.10	1.048	1.000
LOELEV ^{D}	-1.17	0.20	-0.11	0.29	-3.118	**0.027**
MIDELEV ^{D}	0.00	0.15	0.09	0.21	-0.376	1.000
HIELEV ^{D}	1.51	0.24	0.08	0.18	4.436	**<0.001**
SLSL ^{D}	-0.54	0.14	0.45	0.22	-3.988	**0.002**
MSLOPE ^{D}	0.65	0.10	0.02	0.16	3.571	**0.007**
HSLOPE ^{D}	1.27	0.21	0.25	0.28	2.999	**0.038**
Vegetative Cover						
ALPINE $^{D, E}$	1.14	0.20	-0.10	0.15	4.681	**<0.001**
BROADLEAF ^{D}	0.19	0.14	0.35	0.17	-0.748	1.000
SHRUB $^{D, E}$	0.58	0.17	0.09	0.19	1.901	0.677
CONIFER ^{D}	-0.15	0.12	-0.06	0.17	-0.454	1.000
MIXED $^{D, E}$	-0.97	0.15	0.03	0.20	-4.082	**0.001**
WET ^{D}	-0.60	0.15	-0.05	0.19	-2.301	0.269
Drainage Feature Codes						
BUFF50 ^{D}	-0.10	0.14	-0.18	0.20	0.358	1.000
BUFF15	-0.05	0.15	-0.13	0.13	0.393	1.000
BUFF15MIDHI	0.77	0.15	0.26	0.25	1.831	0.214

Table 6. (Continued)

Variable	High		Low		Test Statistic [A]	
	Mean	SE	Mean	SE	*t*	*P* [B]
Burned Area Codes						
BURN LT 1974 [C]	0.04	0.15	0.49	0.32	566.00	1.000
BURN 74_99 [C, D, E]	-0.20	0.12	-0.06	0.19	576.00	1.000
TTL BURN [C, D]	-0.13	0.14	0.34	0.25	512.00	0.534
Patch Characteristics						
NUMPATCH [D, E]	-0.89	0.12	0.32	0.23	-5.152	**<0.001**
MPS	0.04	0.01	-0.01	0.01	4.525	**<0.001**
TE	-0.93	0.12	0.31	0.23	-5.140	**<0.001**
MPE	0.87	0.16	-0.17	0.17	4.169	**0.001**
SDI [D]	-0.57	0.13	0.06	0.17	-2.982	**0.043**

[A] Two-sample *t*-test; d.f. = 69

[B] Bonferroni adjusted probabilities.

[C] Mann-Whitney *U*-test, d.f. = 1

[D] Variables used in multivariate analysis, after testing for multicollinearity.

[E] Variables used in AIC modeling.

Table 7. Moose population density estimates based on early winter aerial surveys within the study area in west central Yukon, 1998 and 1999.

Surveys	Moose Observed	Estimated Population	Estimated Density /1000 km^2	± 90% confidence interval
1998	303	951	173	19.4%
1999	332	1225	222	18.9%

Table 8. Land cover classification for the study area in west central Yukon. Shaded rows are unvegetated classes.

Cover Type	Cover Name	Description/ Dominant Species	% of Study Area
Shrub	SHRUB	*Betula spp.* *Willow spp.* *Alnus spp.*	27.70
Conifer forest	CONIFER	*Picea mariana* *Picea glauca*	19.84
Muskeg	WET	Muskeg/bog	15.27
Mixed (broadleaf/ conifer) forest	MIXED	*Picea glauca* *Populous tremuloides* *Populus balsamifer* *Betula papyrifera*	13.08
Broadleaf forest	BROADLEAF	*Populus tremuloides* *Populus balsamifer* *Betula papyrifera*	11.26
Alpine	ALPINE	*Non-forested land above timberline (~1200m)* *Betula spp.* *Salix spp.*	8.42
Unvegetated (cloud shadow, exposed land, sparse vegetation)	UNVEG	N/A	2.8
Water	WATER	N/A	<1.00
Clouds	CLOUDS	N/A	<1.00

Table 9. Parameter estimates for the LOGIT model for topographic variables for survey blocks where moose were present (n = 54) and absent (n = 17) in early winter in west central Yukon, 1998 and 1999. Reported are the parameter estimate (β), the coefficient standard error (SE), and odds ratio with 95% confidence intervals (CI).

Variable	***β***	**SE**	**Odds Ratio (95% CI)**
Constant	0.738	0.310	-
HIELEV	1.025	0.324	2.788 (1.477-5.262)

Table 10. Parameter estimates for the LOGIT model for vegetated variables for survey blocks where moose were present (n = 54) and absent (n = 17) in early winter in west central Yukon, 1998 and 1999. Reported are the parameter estimate (β), the coefficient standard error (SE), and odds ratio with 95% confidence interval (CI).

Variable	***β***	**SE**	**Odds Ratio (95% CI)**
Constant	1.112	0.338	-
MIXED	-0.991	0.335	0.371 (0.193-0.716)
BROADLEAF	-1.088	0.422	0.337 (0.147-0.771)
WET	-0.630	0.342	0.532 (0.272-1.042)[A]

[A] 95% CI includes the value of 1; variable is not considered a useful predictor since the direction of selection can not be determined.

Table 11. Parameter estimates for the LOGIT model for habitat variables for survey blocks where moose were present (n = 54) and absent (n = 17) in early winter in west central Yukon, 1998 and 1999. Reported are the parameter estimate (β), the coefficient standard error (SE), and odds ratio with 95% confidence interval (CI).

Variable	***β***	**SE**	**Odds Ratio (95% CI)**
Constant	1.1014	0.330	-
NUMPATCH	-1.128	0.334	0.324 (0.168-0.622)

Table 12. Ranking of 99.99% confidence set of models used to explain differences in survey blocks where moose were present (n = 54) and absent (n = 17) in early winter in west central Yukon, 1998 and 1999. Reported are the bias-corrected Akaike Information Criteria (AIC_c), the number of model parameters (K), the difference in AIC_c values between each model and the lowest AIC_c value (Δ_i), and Akaike weights (w_i). Dotted line indicates where $\Delta_i < 2$.

Model	**AIC_c**	**K**	**Δ_i**	**w_i**	**Evidence Ratios**	**Classification Accuracy (%)**	
						Present	**Absent**
Number of patches	64.720	2	0.000	0.245	-	81.9	42.4
Number of patches + shrub	65.138	3	0.418	0.199	1.231	82.2	43.5
Number of patches + burn74-99	66.308	3	1.588	0.111	2.207	82.1	43.3
Number of patches + mixed	66.590	3	1.870	0.096	2.552	81.9	42.5
Number of patches + alpine	66.726	3	2.006	0.090	2.722	81.9	42.4
Number of patches + alpine + shrub	67.344	4	2.624	0.066	3.712	82.2	43.4
Number of patches + alpine + burn74_99	68.414	4	3.694	0.039	6.282	82.1	43.3
Number of patches + alpine + mixed	68.802	4	4.082	0.032	7.656	81.9	42.5
Number of patches + alpine + burn74_99 + shrub	69.239	5	4.519	0.026	9.423	82.5	44.3
Number of patches + mixed + burn74_99 + shrub	69.263	5	4.543	0.025	9.800	82.5	44.3
Number of patches + alpine + mixed + shrub	69.647	5	4.927	0.021	11.667	82.2	43.5
Number of patches + alpine + mixed + burn 74_99	70.523	5	5.803	0.013	18.846	82.2	43.5
Number of patches + alpine + mixed + burn 74_99 + shrub	71.627	6	6.906	0.008	30.625	82.5	44.3
Alpine + shrub	72.254	3	7.534	0.006	40.833	79.6	35.3
Alpine + burn 74_99	72.554	3	7.834	0.005	49.000	79.1	33.7

Table 12. (Continued)

Model	**AIC$_c$**	**K**	**Δ_i**	**w_i**	**Evidence Ratios**	**Classification Accuracy**	
						Present	**Absent**
Mixed	72.562	2	7.842	0.005	49.000	79.3	34.2
Alpine	72.694	2	7.974	0.005	49.000	78.7	32.4
Alpine + mixed	73.082	3	8.362	0.004	61.250	79.5	35.0
Mixed + shrub	73.838	3	9.118	0.003	81.667	79.5	34.9
Mixed + burn74_99	73.880	3	9.160	0.003	81.667	79.6	35.3

Table 13. Parameter estimates for the AIC$_c$ model with $\Delta_i = 0.000$ for survey blocks where moose were present (n = 54) and absent (n = 17) in early winter in west central Yukon, 1998 and 1999. Reported are the parameter estimate (β), the coefficient standard error (SE), and odds ratio with 95% confidence intervals (CI).

Variable	β	SE	Odds Ratio (95% CI)
Constant	1.014	0.324	-
NUMPATCH	-1.128	0.318	0.324 (0.174-0.603)

Table 14. Parameter estimates for the AIC$_c$ model with $\Delta_i = 0.418$ for survey blocks where moose were present (n = 54) and absent (n = 17) in early winter in west central Yukon, 1998 and 1999. Reported are the parameter estimate (β), the coefficient standard error (SE), and odds ratio with 95% confidence interval (CI).

Variable	β	SE	Odds Ratio (95% CI)
Constant	0.976	0.331	-
NUMPATCH	-1.033	0.334	0.356 (0.185-0.686)
SHRUB	0.490	0.320	1.633 (0.873-3.054)[A]

[A] 95% CI includes the value of 1; variable is not considered a useful predictor since the direction of selection can not be determined.

Table 15. Parameter estimates for the LOGIT model for topographic variables for survey blocks with high numbers of adult moose (≥ 2 moose, *n* = 42) and low numbers of adult moose (< 2 moose, *n* = 29) in early winter in west central Yukon, 1998 and 1999. Reported are the parameter estimate (β), the coefficient standard error (SE), and odds ratio with 95% confidence intervals (CI).

Variable	***β***	**SE**	**Odds Ratio (95% CI)**
Constant	-0.158	0.299	-
SE	-0.829	0.516	0.437 (0.159-1.200)[A]
HIELEV	0.949	0.246	2.583 (1.595-4.182)

[A] 95% CI includes the value of 1; variable is not considered a useful predictor since the direction of selection can not be determined.

Table 16. Parameter estimates for the LOGIT model for vegetated variables for survey blocks with high numbers of adult moose (≥ 2 moose, *n* = 42) and low numbers of adult moose (< 2 moose, *n* = 29) in early winter in west central Yukon, 1998 and 1999. Reported are the parameter estimate (β), the coefficient standard error (SE), and odds ratio with 95% confidence interval (CI).

Variable	***β***	**SE**	**Odds Ratio (95% CI)**
Constant	-0.123	0.300	-
ALPINE	1.115	0.244	3.048 (1.891-4.913)

Table 17. Parameter estimates for the LOGIT model for habitat variables for survey blocks with high numbers of adult moose (≥ 2 moose, $n = 42$) and low numbers of adult moose (< 2 moose, $n = 29$) in early winter in west central Yukon, 1998 and 1999. Reported are the parameter estimate (β), the coefficient standard error (SE), and odds ratio with 95% confidence interval (CI).

Variable	β	**SE**	**Odds Ratio (95% CI)**
Constant	-0.159	0.298	-
TTLBURN	-0.652	0.261	0.521 (0.312-0.869)
NUMPATCH	-1.480	0.387	0.228 (0.107-0.486)

Table 18. Ranking of 99.99% confidence set of models used to explain differences between survey blocks with high numbers of adult moose (≥ 2 moose, $n = 42$) and low numbers of adult moose (< 2 moose, $n = 29$) in early winter in west central Yukon, 1998 and 1999. Reported are the bias-corrected Akaike Information Criteria (AIC$_c$), the number of model parameters (K), the difference in AIC$_c$ values between each model and the lowest AIC$_c$ value (Δ_i), and Akaike weights (w_i). Dotted line indicates where $\Delta_i < 2$.

Model	**AIC$_c$**	**K**	**Δ_i**	**w_i**	**Evidence Ratios**	**Classification Accuracy (%)**	
						Present	**Absent**
Number of patches + alpine	76.440	3	0.000	0.244	-	71.9	59.3
Number of patches	77.908	2	1.468	0.117	2.082	70.6	57.4
Number of patches + alpine + burn 74_99	78.180	4	1.740	0.102	2.385	72.2	59.7
Number of patches + alpine + mixed	78.680	4	2.240	0.080	3.062	71.9	59.3
Number of patches + alpine + shrub	78.688	4	2.248	0.079	3.074	71.9	59.3
Number of patches + mixed	79.306	3	2.866	0.058	4.188	71.0	57.8
Number of patches + burn74_99	79.616	3	3.176	0.050	4.890	70.9	57.9
Alpine	80.048	2	3.608	0.040	6.069	69.0	55.1
Number of patches + shrub	80.084	3	3.644	0.039	6.179	70.6	57.4
Number of patches + alpine + mixed + burn 74_99	80.481	5	4.041	0.032	7.535	72.2	59.8
Number of patches + alpine + shrub + burn 74_99	80.491	5	4.051	0.032	7.573	72.2	59.7
Number of patches + alpine + shrub + mixed	80.989	5	4.549	0.025	9.714	71.9	59.3
Alpine + mixed	81.088	3	4.648	0.024	10.208	69.8	56.3
Alpine + burn74_99	81.610	3	5.170	0.018	13.252	69.3	55.6
Alpine + shrub	81.778	3	5.338	0.017	14.413	69.4	55.7
Alpine + mixed + burn74_99	82.698	4	6.258	0.011	22.830	70.2	56.8

Table 18 (continued).

Model	AIC$_c$	K	Δ_i	w_i	Evidence Ratios	Classification Accuracy (%)	
						Present	Absent
Number of patches + alpine + mixed + shrub + burn 74_99	82.843	6	6.403	0.010	24.539	72.2	59.7
Number of patches + mixed + shrub + burn 74_99	83.129	5	6.689	0.009	28.320	71.3	58.5
Alpine + mixed + shrub	83.332	4	6.892	0.008	31.345	69.8	56.3
Alpine + mixed + burn74_99 + shrub	85.015	5	8.575	0.003	72.717	70.2	56.8

Table 19. Parameter estimates for the AIC$_c$ model with $\Delta_i = 0.000$ for survey blocks with high numbers of adult moose (≥ 2 moose, $n = 42$) and low numbers of adult moose (< 2 moose, $n = 29$) in early winter in west central Yukon, 1998 and 1999. Reported are the parameter estimate (β), the coefficient standard error (SE), and odds ratio with 95% confidence intervals (CI).

Variable	β	**SE**	**Odds Ratio (95% CI)**
Constant	-0.227	0.314	-
NUMPATCH	-0.852	0.348	0.426 (0.216-0.843)
ALPINE	0.657	0.299	1.928 (1.073-3.467)

Table 20. Parameter estimates for the AIC$_c$ models with $\Delta_i = 1.468$ for survey blocks with high numbers of adult moose (≥ 2 moose, $n = 42$) and low numbers of adult moose (< 2 moose, $n = 29$) in early winter in west central Yukon, 1998 and 1999. Reported are the parameter estimate (β), the coefficient standard error (SE), and odds ratio with 95% confidence interval (CI).

Variable	β	**SE**	**Odds Ratio (95% CI)**
Constant	-0.103	0.298	-
NUMPATCH	-1.280	0.304	0.278 (0.153-0.505)

Table 21. Parameter estimates for the AIC$_c$ models with $\Delta_i = 1.740$ for survey blocks with high numbers of adult moose (≥ 2 moose, $n = 42$) and low numbers of adult moose (< 2 moose, $n = 29$) in early winter in west central Yukon, 1998 and 1999. Reported are the parameter estimate (β), the coefficient standard error (SE), and odds ratio with 95% confidence interval (CI).

Variable	**β**	**SE**	**Odds Ratio (95% CI)**
Constant	-0.284	0.304	-
NUMPATCH	-0.849	0.351	0.428 (0.215-0.852)
BURN74-99	-0.277	0.233	0.758 (0.480-1.197)[A]
ALPINE	0.664	0.300	1.942 (1.079-3.496)

[A] 95% CI includes the value of 1; variable is not considered a useful predictor since the direction of selection can not be determined.

FIGURES

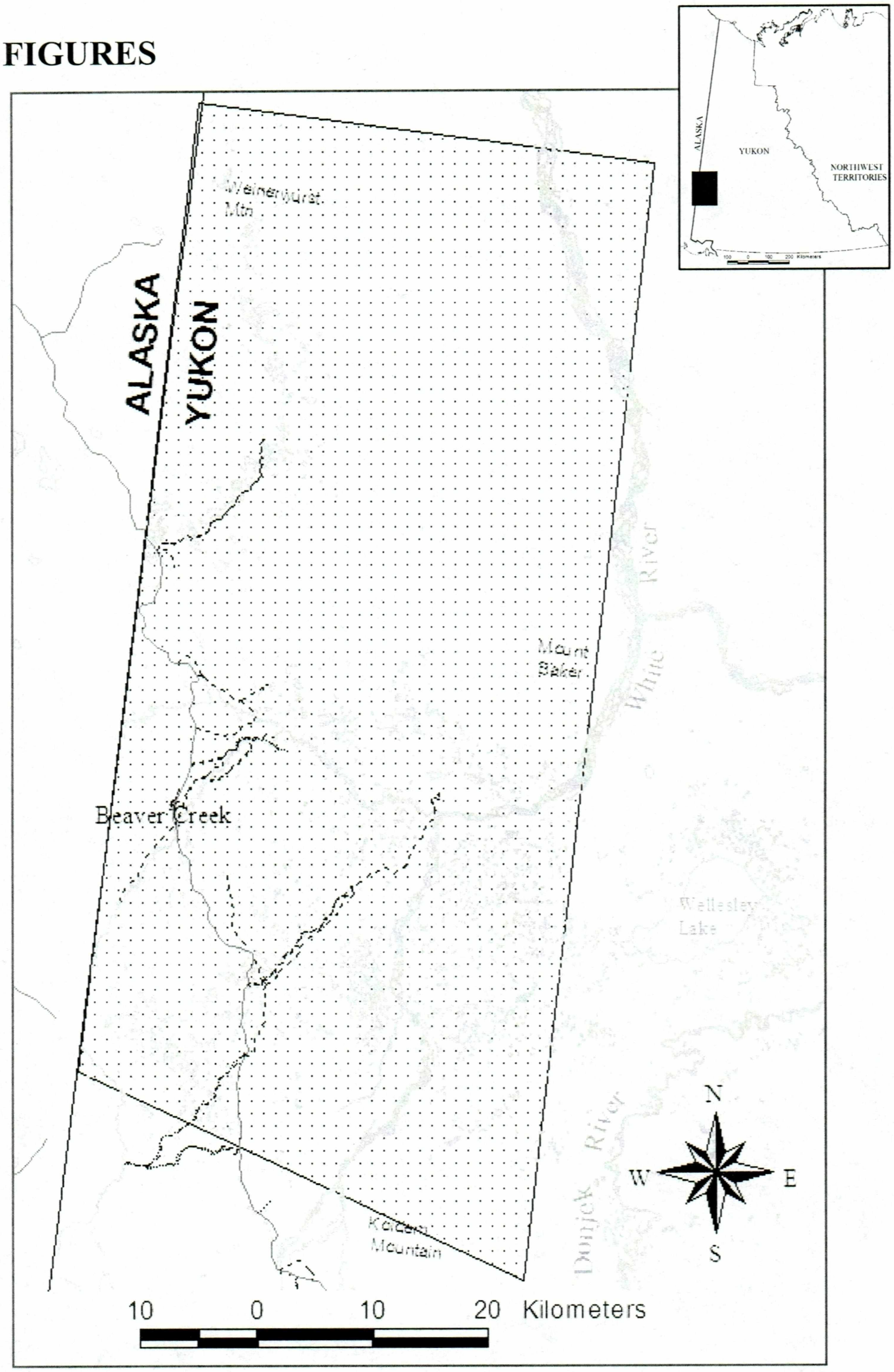


Figure 1. Location of the study area (dotted polygon) in west central Yukon. Inset shaded polygon identifies mapped area above.

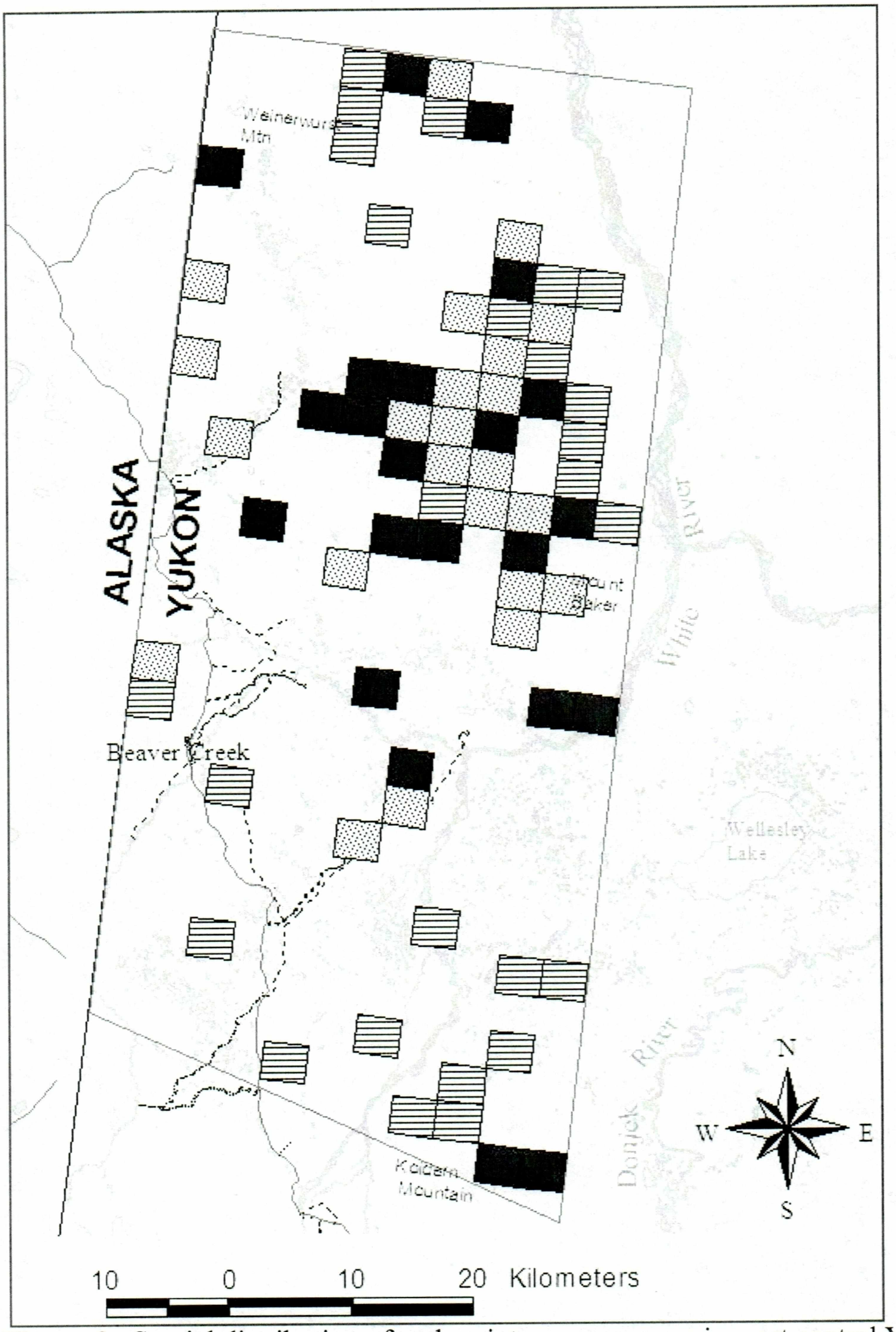


Figure 2. Spatial distribution of early winter survey areas in west central Yukon, 1998 and 1999. Dotted blocks were surveyed in 1998 ($n = 45$), striped blocks were surveyed in 1999 ($n = 48$), and filled blocks were surveyed in 1998 and 1999 ($n = 22$).

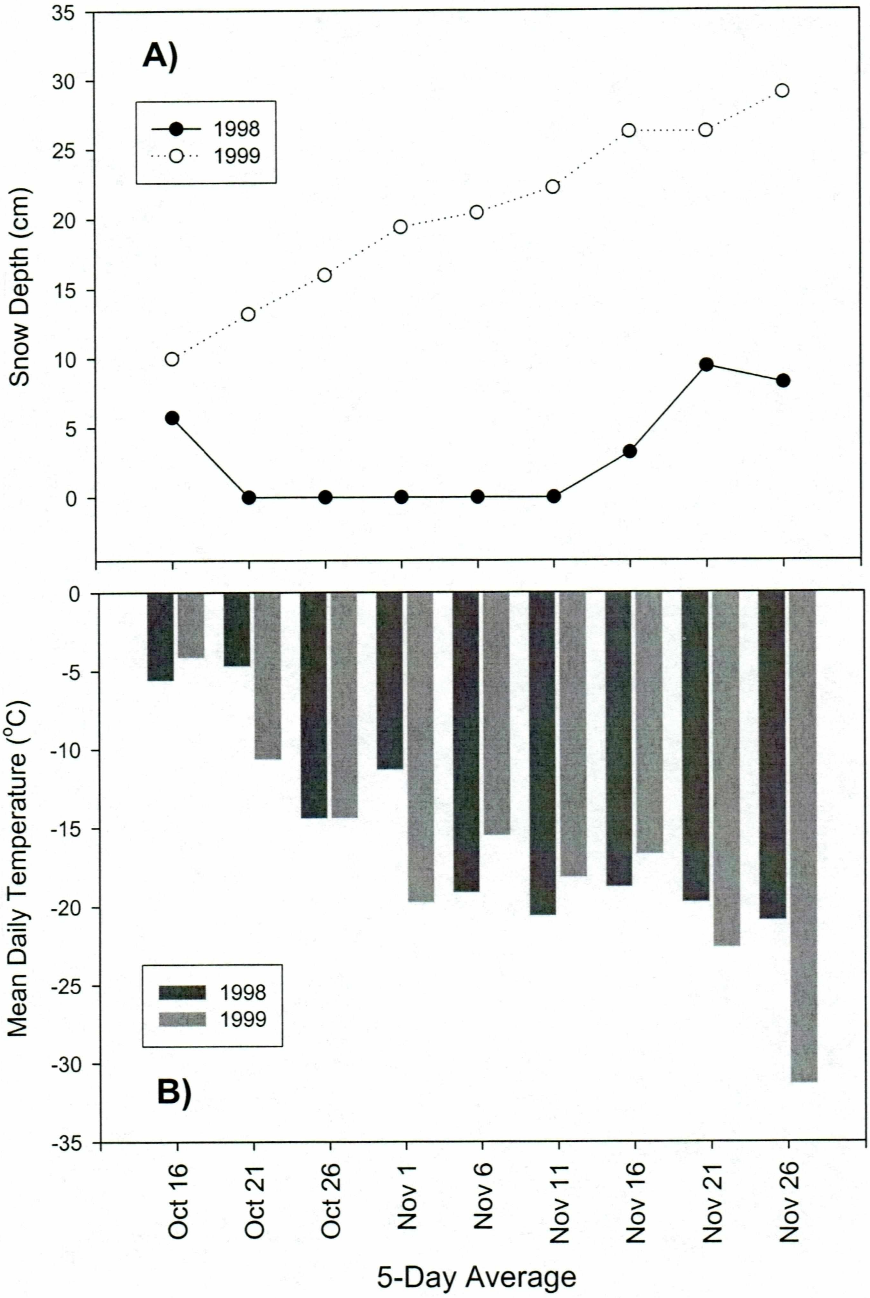


Figure 3. Survey conditions October and November 1998 and 1999 for snow depth (A) and mean daily temperature (B) within the study area in west central Yukon. Surveys were conducted November 18-20, 1998 and October 26-29, 1999.

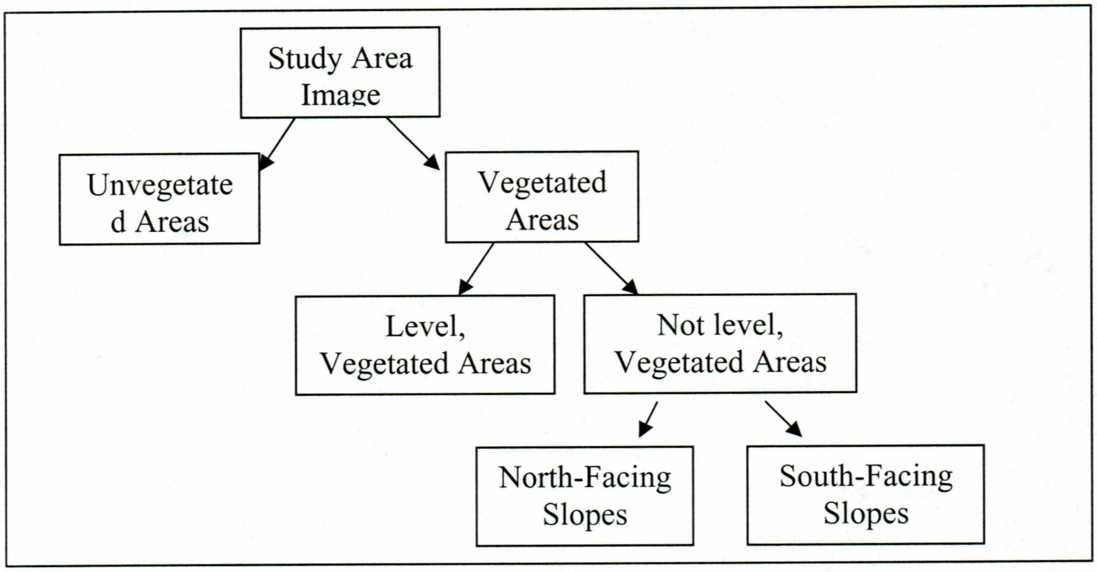


Figure 4. Steps followed to derive a land cover map for the study area in west central Yukon.

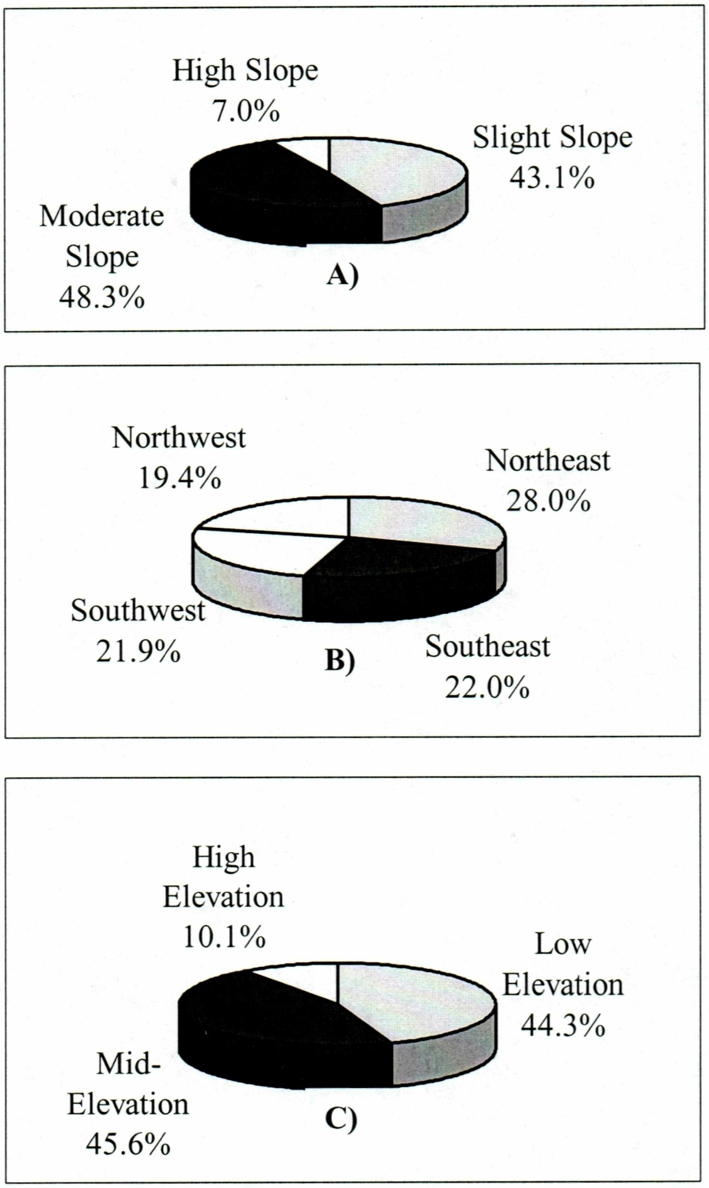


Figure 5. Slope gradient (a), aspect (b), and elevation (c) for the study area in west central Yukon. Values are expressed as a percent of total study area.

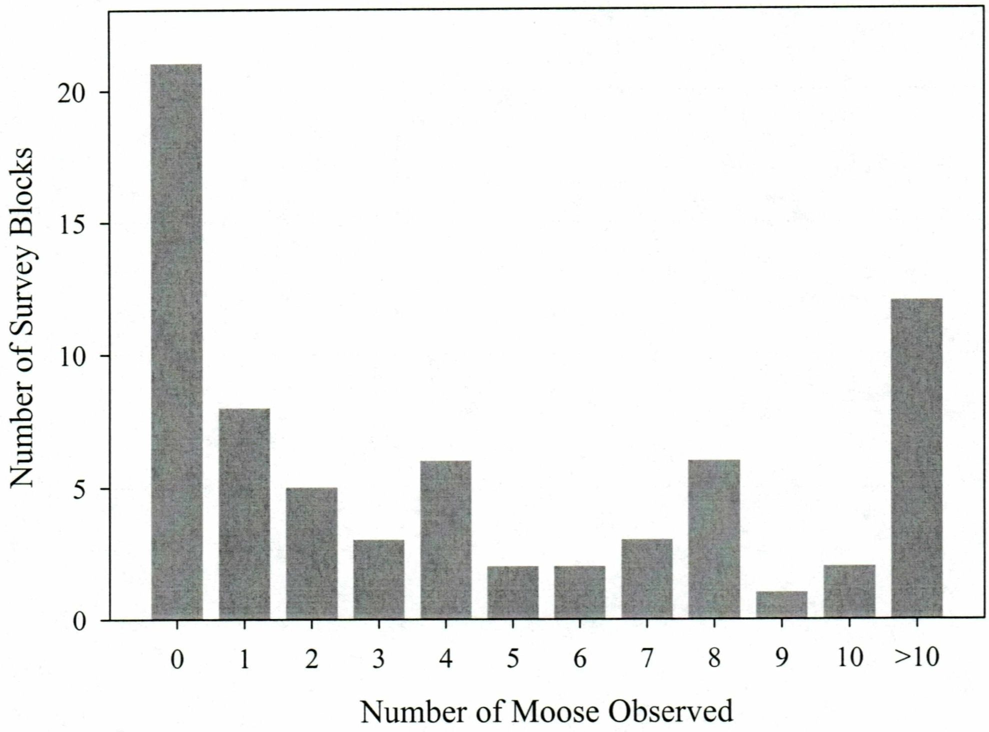


Figure 6. Histogram of moose counts for 1998 and 1999 by number of survey blocks in the study area in west central Yukon.

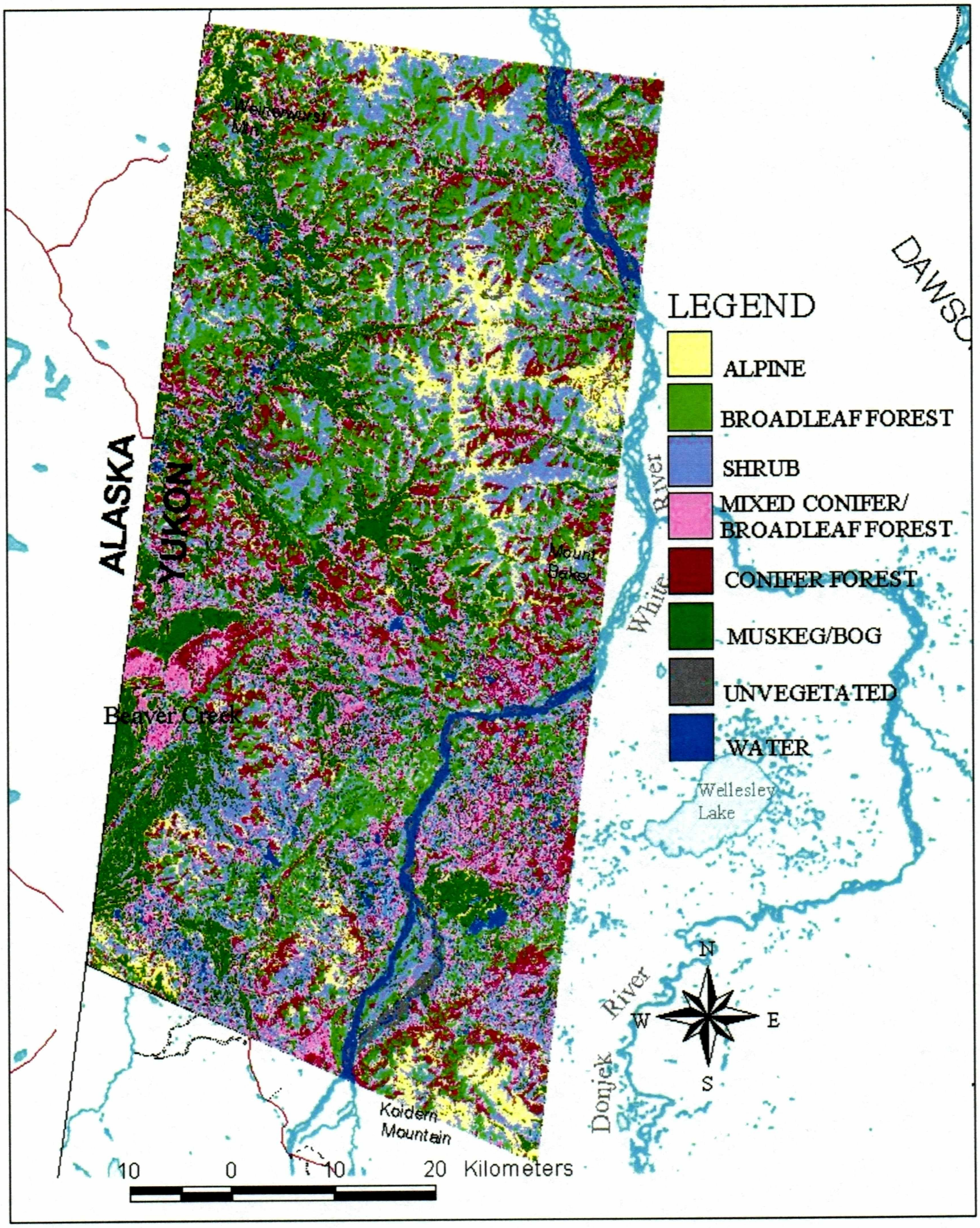


Figure 7. Land cover classification for the study area in west central Yukon.

APPENDICES

APPENDIX A. Image specifications and georectification results.

Table 22. Landsat 5 TM image specifications used in this study.

Track/ Frame	**Date & Time of Acquisition**	**Scene Centre**	**Pixel Dimensions (m)**	**# of links used in registration**	**Model RMS Error (pixels)**
63/17	22 July 1994 19:54:17	62°51'58"N 139°52'01"W	25 x 25 (resampled from 30 x 30 by Radarsat International)	18	1.06

Table 23. Registration errors for image used in this study.

Ground Control Point Segment Report - v. 7.0 EASI/PACE

	Set 2 GCP's		Set 1 GCP's				
	Longitude	Latitude	Pixel				
GCP No.	ACEA	E008			Residual		Distance
13	167262.0	853469.2	7200.5	4813.0	0.09	1.50	1.50
2	146682.2	847711.2	6415.4	5148.0	0.97	-1.09	1.45
8	71423.8	881813.7	3246.0	4200.0	1.41	0.20	1.43
17	177855.5	905024.1	7344.3	2714.9	-0.44	1.20	1.28
9	99563.1	882654.4	4355.9	4017.1	-1.07	0.46	1.16
11	157888.2	887319.5	6647.0	3520.0	-0.05	-1.13	1.13
3	93915.4	908260.8	3995.0	3032.2	-0.69	-0.65	0.95
4	113219.7	862116.1	5009.0	4758.0	-0.10	0.93	0.94
5	170400.0	971374.7	6694.2	125.9	0.84	-0.33	0.91
18	158999.0	867729.0	6795.9	4290.0	-0.17	-0.85	0.87
14	116299.8	969055.6	4558.1	507.0	-0.37	0.65	0.75
10	120105.6	932322.9	4906.8	1941.0	0.49	0.51	0.71
1	120396.5	900870.2	5085.8	3183.9	-0.55	-0.43	0.70
15	102083.9	897187.6	4379.1	3427.1	-0.06	-0.62	0.62
7	145697.9	915823.9	6010.1	2457.0	-0.38	-0.47	0.60
12	71212.3	912735.4	3070.3	2977.0	-0.22	0.43	0.48
16	73168.1	966702.6	2859.3	829.1	0.23	-0.29	0.37
6	75724.4	939013.8	3109.0	1912.0	0.07	-0.02	0.08
				RMS =	0.66	0.83	1.06

APPENDIX B. Description of variables used in this study.

Table 24. Description of mnemonic codes for topographic, vegetative cover, drainage features, wildfire burn, and patch characteristics variables used in the analysis of moose presence/absence and high/low numbers of observed adult moose, for a study area in west central Yukon, early winter 1998 and 1999.

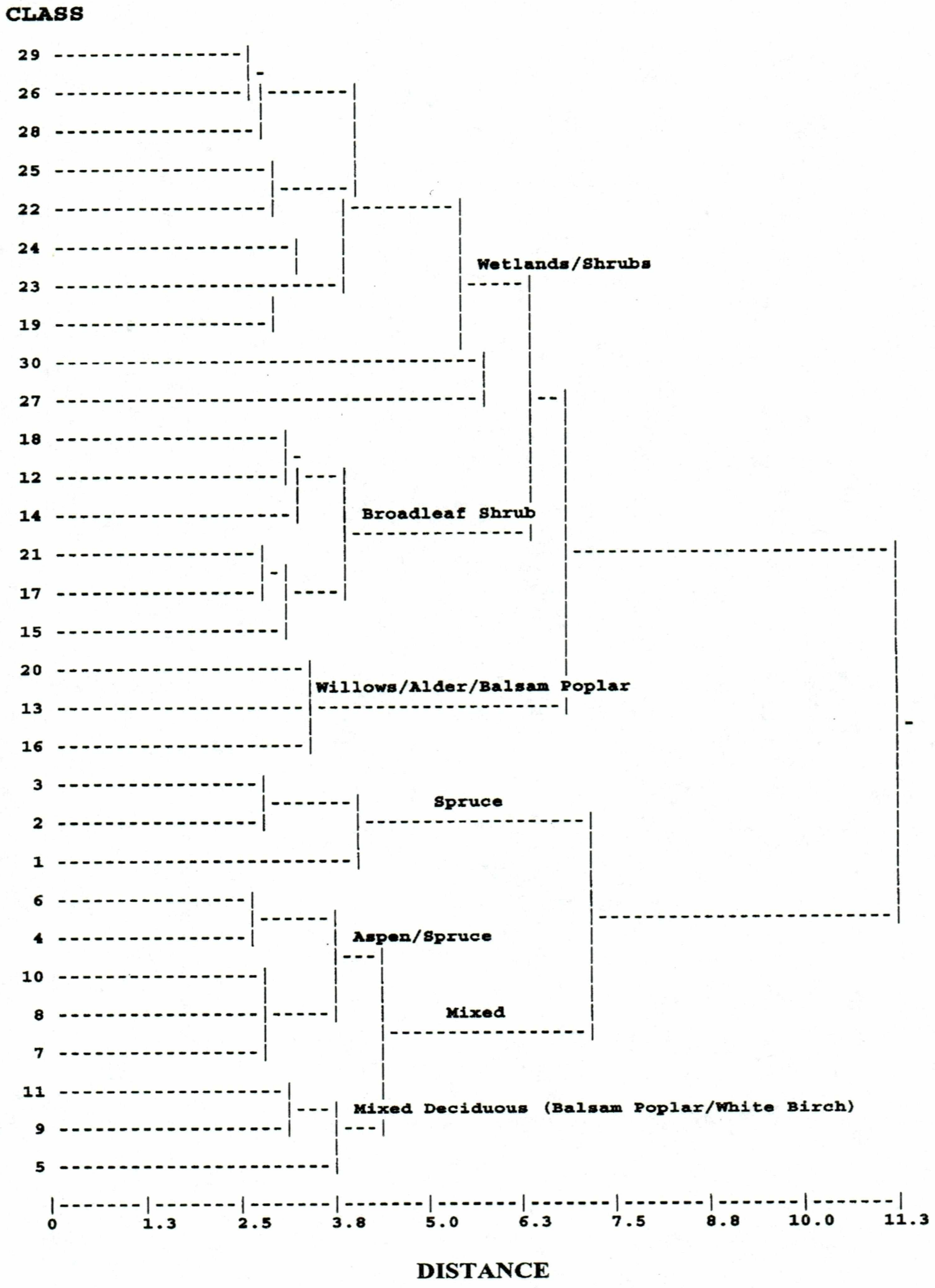
Mnemonic Code	Variable Description
Topographic Codes	
NE	% of survey block with an aspect < 90 degrees
SE	% of survey block with an aspect ≥ 90 and < 180 degrees
SW	% of survey block with an aspect ≥ 180 and < 270 degrees
NW	% of survey block with an aspect ≥ 270 and < 360 degrees
LOELEV	% of survey block with an elevation < 673 m
MIDELEV	% of survey block with an elevation between 674-999 m
HIELEV	% of survey block with an elevation ≥ 1000 m
SLSL	% of survey block with slope gradient between 0-3 degrees
MSLOPE	% of survey block with slope gradient between 4-20 degrees
HSLOPE	% of survey block with slope gradient > 20 degrees
Vegetative Cover Codes	
ALPINE	% of survey block alpine (non-forested land above timberline)
BROADLEAF	% of survey block dominated by broadleaf forest
SHRUB	% of survey block dominated by shrubs, including areas of regeneration
CONIFER	% of survey block dominated by conifer forest
MIXED	% of survey block dominated by mixed conifer, broadleaf forest
WET	% of survey block dominated by low-lying muskeg/bog

Table 24. (Continued)

Mnemonic Code	Variable Description
Drainage Feature Codes	
BUFF50	% of survey block within 50m buffer of linear drainage (creek, river)
BUFF15	% of survey block within 15m buffer of linear drainage (creek, river)
BUFF15MIDHI	% of survey block within 15m buffer of linear drainage (creek, river) above 674m elevation
Wildfire Burn Codes	
BURN LT 1974	% of survey block burned 1951-1974
BURN 74_99	% of survey block burned 1974-1999
TTL BURN	% of survey block burned 1951-1999
Patch Characteristic Codes	
NUMPATCH	Number of patches, by survey block
MPS	Mean patch size (km^2), by survey block
TE	Total edge (km), by survey block
MPE	Mean patch edge (km/patch), by survey block
SDI	Shannon's Diversity Index – a measure of relative patch diversity (the index will equal zero when there is only one patch on the landscape and increases as the number of patch types or proportional distribution of patch types increases (McGarigal and Marks, 1994).

APPENDIX C. Example dendrogram generated from the unsupervised classification in this study.

Figure 8. Dendrogram for level, vegetated coverage, 30 classes.



APPENDIX D. Box and whisker plots of variables used in AIC modeling

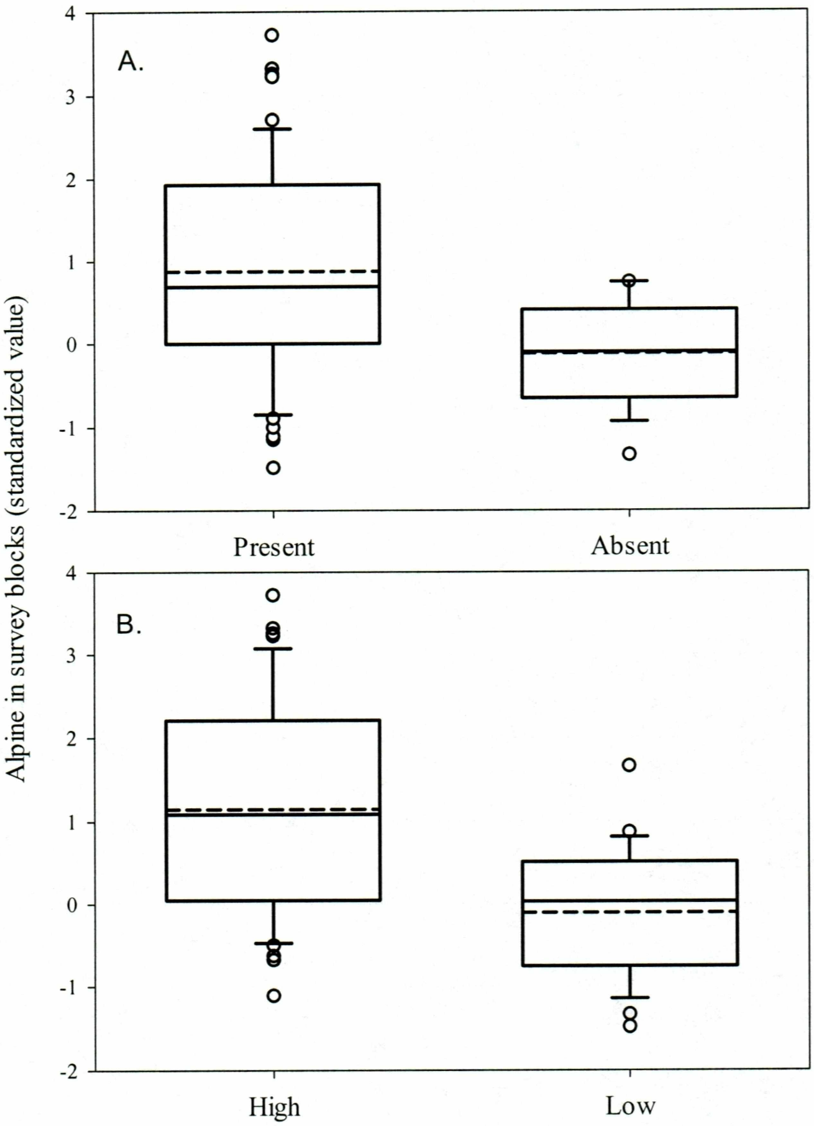


Figure 9. Standardized values representing percent of survey block alpine with a) moose present (*n* = 54) and moose absent (*n* = 17) and b) high (≥ 2 moose; *n* = 42) and low (< 2 moose; *n* = 29) numbers of observed adult moose, in west central Yukon, early winter 1998 and 1999. Dashed line represents the mean. Boxes depict 50 percent of observations. Whiskers depict upper 95% and lower 5% of observations. Dots depict outlying observations. Dashed line represents the mean, solid line represents the median.

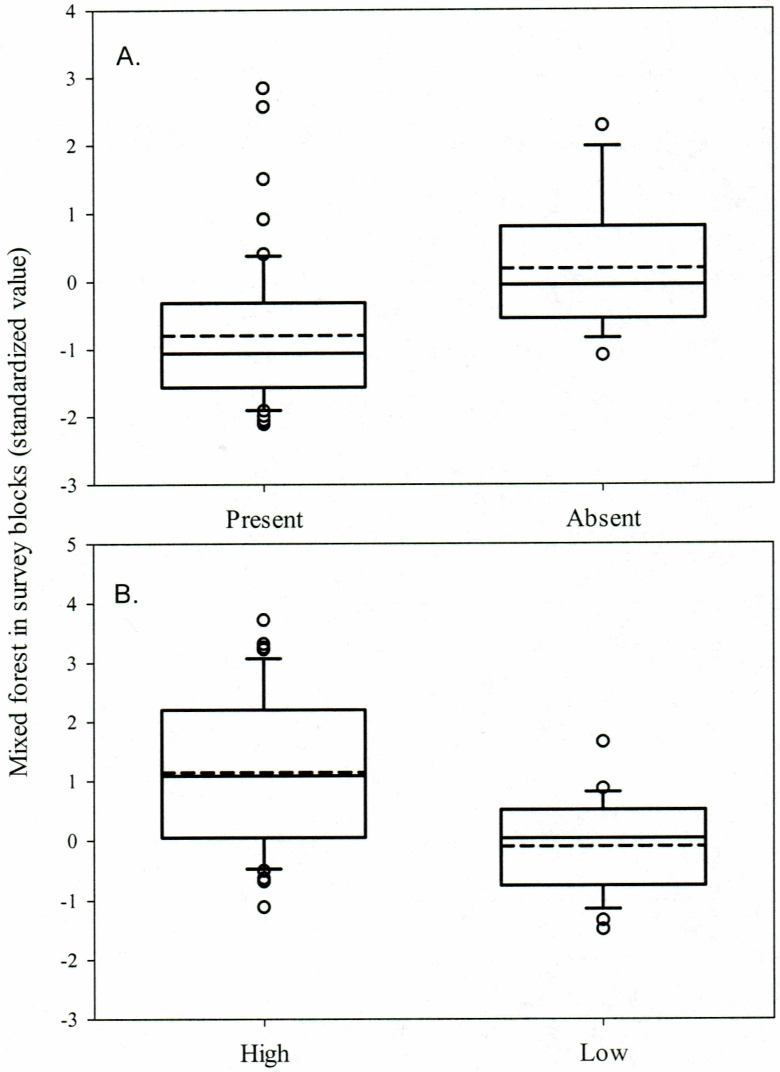


Figure 10. Standardized values representing percent of survey block dominated by mixed forest with a) moose present ($n = 54$) and moose absent ($n = 17$) and b) high (≥ 2 moose; $n = 42$) and low (< 2 moose; $n = 29$) numbers of observed adult moose, in west central Yukon, early winter 1998 and 1999. Boxes depict 50 percent of observations. Whiskers depict upper 95% and lower 5% of observations. Dots depict outlying observations. Dashed line represents the mean, solid line represents the median.

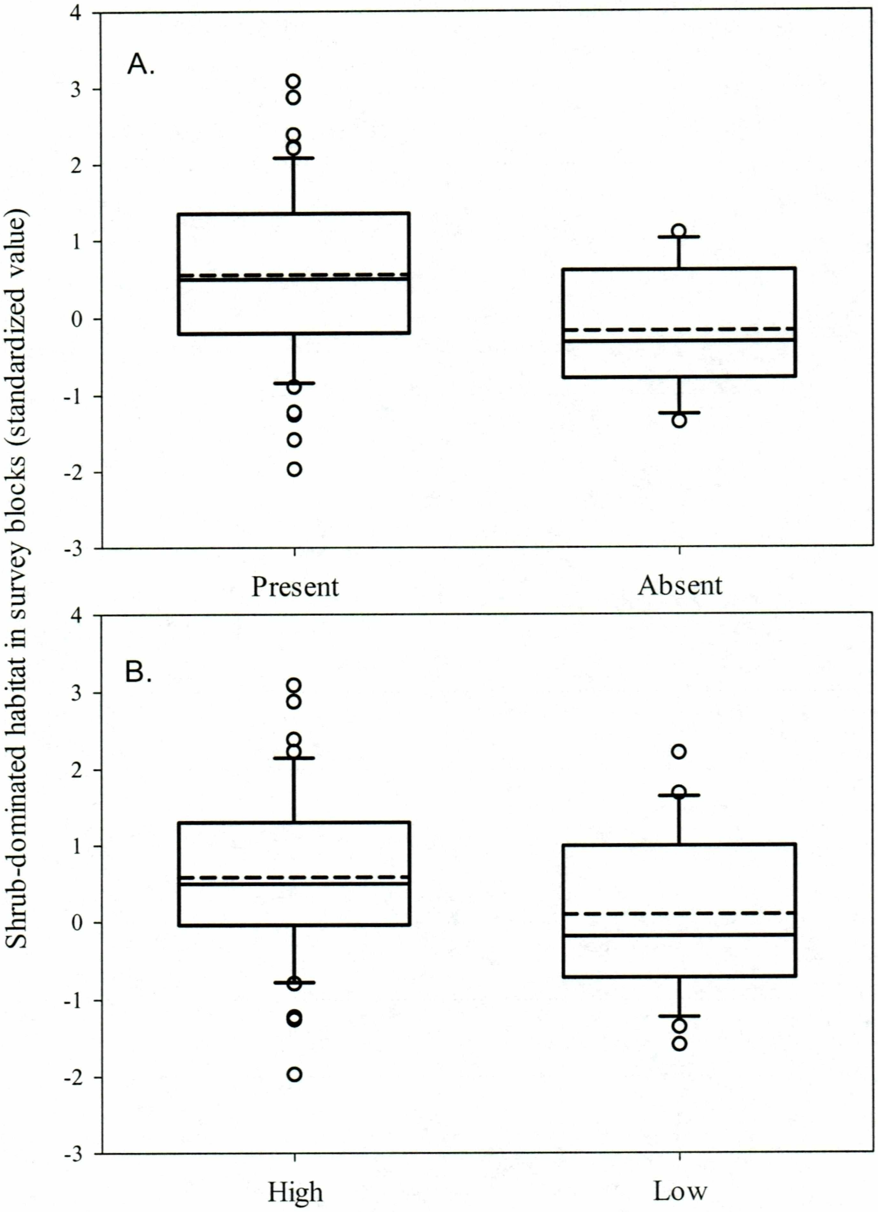


Figure 11. Standardized values representing percent of survey block dominated by shrubs with a) moose present (*n* = 54) and moose absent (*n* = 17) and b) high (≥ 2 moose; *n* = 42) and low (< 2 moose; *n* = 29) numbers of observed adult moose, in west central Yukon, early winter 1998 and 1999. Boxes depict 50 percent of observations. Whiskers depict upper 95% and lower 5% of observations. Dots depict outlying observations. Dashed line represents the mean, solid line represents the median.

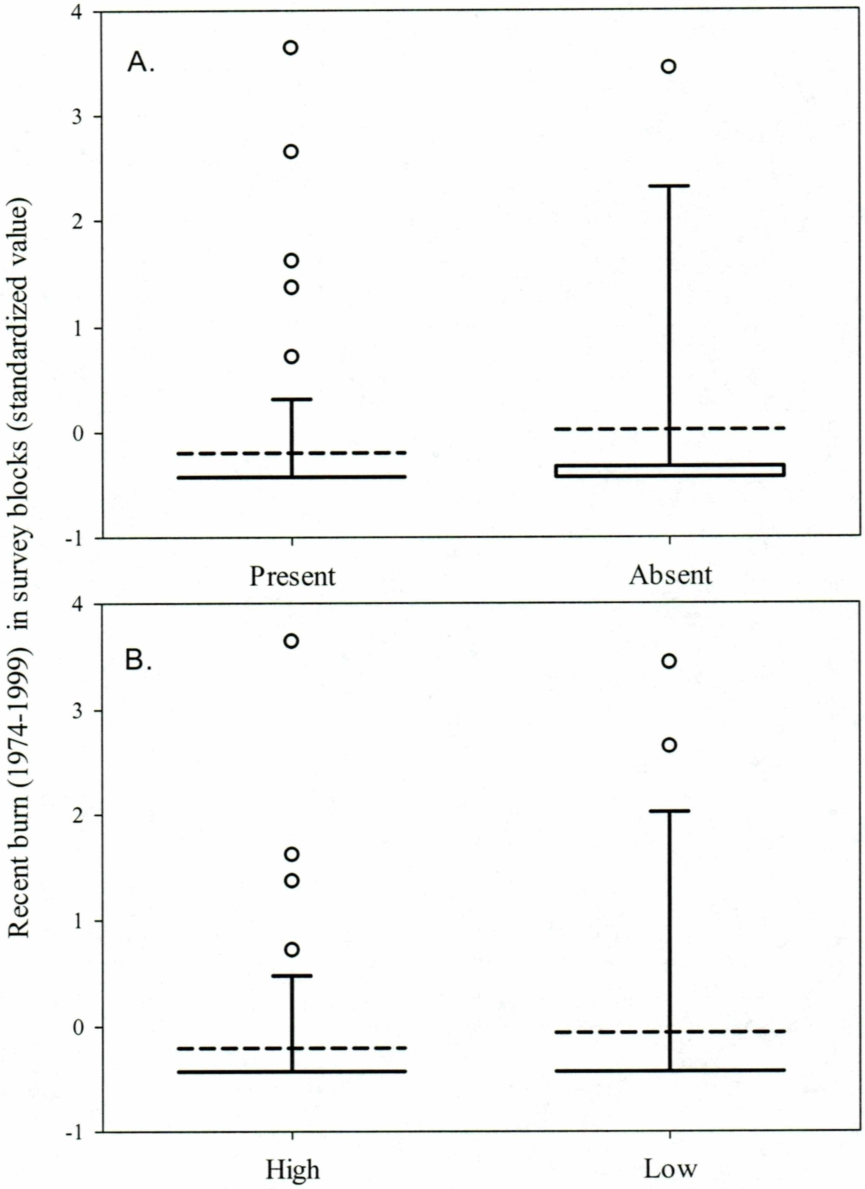


Figure 12. Standardized values representing percent of survey block burned 1974-1999 with a) moose present (*n* = 54) and moose absent (*n* = 17) and b) high (≥ 2 moose; *n* = 42) and low (< 2 moose; *n* = 29) numbers of observed adult moose, in west central Yukon, early winter 1998 and 1999. Boxes depict 50 percent of observations. Whiskers depict upper 95% and lower 5% of observations. Dots depict outlying observations. Dashed line represents the mean, solid line represents the median.

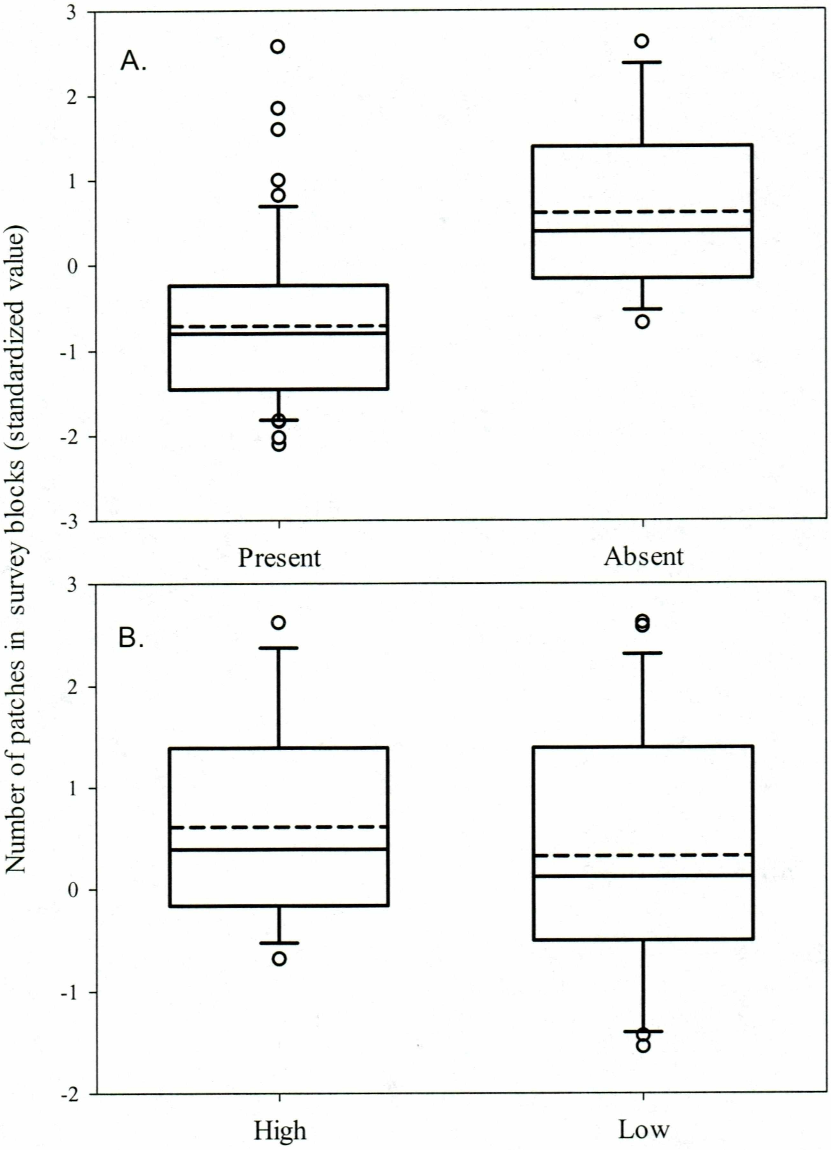


Figure 13. Standardized values representing number of patches by survey block with a) moose present (*n* = 54) and moose absent (*n* = 17) and b) high (≥ 2 moose; *n* = 42) and low (< 2 moose; *n* = 29) numbers of observed adult moose, in west central Yukon, early winter 1998 and 1999. Boxes depict 50 percent of observations. Whiskers depict upper 95% and lower 5% of observations. Dots depict outlying observations. Dashed line represents the mean, solid line represents the median.